# SILICON CHIP

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## ACTIVE LOOP AM ANTENNA:

Here's a cheap'n'easy project which can dramatically improve your AM radio reception!

## Review:

In-depth look at Agilent's incredible new DS05054A Oscilloscope

## Rolling Code Security System:

It's as safe as houses!

## Can you beat OSCAR?

21st century noughts and crosses!

## PICPROBE

A PIC-based logic probe that fits inside a Biro!

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# Publisher's Letter

## Cheap DVD players are just that: cheap!

If ever there was a great example of the march of technology rendering appliances cheaper, it has to be DVD players. Considering that it is not too many years ago that typical DVD players cost $1000 or more, today's sub $50 price is incredible. Not only that but today's cheap DVD players will play just about anything. Some of them would probably even play a wet beer coaster, provided they were round and fitted in the disk drawer. Well, maybe they're not quite that capable but you get the idea.

Just recently, the cheapest-ever DVD player was a Tevion brand unit from Aldi stores priced at just $39! No doubt, there are even cheaper examples available on eBay. The question which must be asked is: just how do they do it? It must mean that the factory price is incredibly low. And it is not just one factory in Asia that is doing this – there are thousands of factories right throughout Asia.

Nor are these machines short on features. Not only will they play all sorts of disk formats, they usually also have a digital display, optical and digital outputs, Dolby 5.1 digital output and volume control via the infrared remote control.

But when you open these machines up, there is not much inside their very light and often quite flimsy chassis. You have the plastic disk player itself, the switchmode power supply and a small PC board carrying one large VLSI chip and otherwise packed with surface-mount devices. If one of these machines fails, it will not be worth getting it repaired – it will go straight to the tip. Even machines which fail during warranty won't be repaired. Such repairs would cost far more than the retail value of the machine.

So what is the downside? Until recently, apart from the ever-growing heap of electronic junk going to the tip, we had not been aware of any downside. Then we became aware of the downside when I purchased that self-same Tevion machine to replace quite an old CD player that I had in my study. When I hooked it up to my equally venerable Harman Kardon AM/FM stereo receiver, I noted that the player sounded OK but certainly not like a really good CD player.

But when I switched across to the AM broadcast band while still leaving the DVD player on, I noticed that the entire AM broadcast band was blotted out. Hmm. There must be quite a lot of radiated hash, I thought. So I picked up a portable radio and yes, there was a great deal of interference. That was bad enough but then I switched across to FM and was staggered to find that the FM reception was blotted out as well.

In normal circumstances, blotting out FM reception is no easy feat. If you wanted to deliberately blot out all FM reception in a limited area, you would have to put out a very strong signal in order to overcome the "capture effect" of a standard FM tuner. But now we have a simple answer – just use a cheap DVD player and amplify the RF rubbish radiated by its audio outputs. This also makes nonsense of any EMC checks that may have been made on this player for C-tick or any other compliance testing

The rest of this story starts on page 10 of this issue and while our survey of DVD players is very limited, it does clearly demonstrate that you still get what you pay for. In other words, if you buy a cheap DVD player, don't expect it to give you hifi quality sound. The same caution might also apply to the video performance of these cheap players although we are inclined to think that since they all tend to use a standard jungle chip inside them, they probably all give quite reasonable performance in that regard. However, we would not suggest that you spend a lot of money on an expensive plasma or LCD TV or an LCD video projector and then team it up with a cheap DVD player. That would be a waste of money!

**Leo Simpson**

# MAILBAG

Letters and emails should contain complete name, address and daytime phone number. Letters to the Editor are submitted on the condition that Silicon Chip Publications Pty Ltd may edit and has the right to reproduce in electronic form and communicate these letters. This also applies to submissions to "Ask Silicon Chip" and "Circuit Notebook".

## LM4562 distortion test method is flawed

Your article on measuring distortion in the LM4562, published in the August 2007 issue, tries to validate a flawed test technique used by National Semiconductor. I recently debunked this in my online forum at:

**http://ska-audio.com/Forum/YaBB.pl?num=1185394996/0#0**

I also detailed this back in 1992 through the letters column of Wireless World when Burr-Brown used much the same technique. It gives great marketable figures but it's not good technique. Now NS have adopted it. The test uses a full unity gain CM signal then effectively divides it by 100 along with the feedback-affected circuit distortions.

Do I have a better way? Well, the scaling method will work OK with inverting mode. Do a x-100 test and divide it for the x1 figure, which in this case will likely be very low. The x100 result could be compared with the existing test result. If there is any difference it could be CM distortion but it would need to be in the same order of magnitude to show.

In short, the dominant distortions in an op amp are common mode distortion, which doesn't generally change greatly with level, and the loop distortion reduced by negative feedback. To use a technique that assesses total distortion in a x100 loop with a x1 common mode signal, and divides the result by 100 for a unity gain distortion result, devalues the CM distortion 100 times as it is already x1 as measured.

Common mode distortion is often the baseline THD of op amps over much of the audio range when operated in non-inverting mode, the loop distortion falling with increasing feedback to just above the open loop pole frequency.

Your measured figure of predominantly 2HD at 0.0025% could well be the x1 CM distortion not x-100 loop distortion. The test is invalid – but great for low figures!

**Greg Ball,**
**Banksia Beach, Qld.**

*Comment: Your letter has been thought provoking to say the least. We were not aware of your debunking. Did Burr-Brown or National Semiconductor ever reply to your criticism?*

*But triggered by your letter, try as we might, we cannot work out any way to measure or estimate CM distortion. The CMRR (common mode rejection ratio) of the LM4562 is -120dB which means that if the op amp has a closed loop gain of say, +20dB, the CM gain will be -100dB. Even if you then apply the maximum permissible CM signal of 20V P-P, the resulting output will only be 0.2mV P-P which is hardly enough to measure or estimate any likely CM distortion.*

*Looking at it another way, if we assume that CM distortion is 10% (ie, really bad), then the CM distortion component of a THD measurement for an LM4562 op amp circuit with a gain of say +10dB, is going to be around -130dB or .00003%. Which is in the ball-park of our measurements!*

*Incidentally, we are not saying that your debunking of the distortion measuring method is wrong but in the case of the LM4562, the difference may simply be academic. Nor do we understand, if the method is inappropriate for a non-inverting op amp, how it can be correct for the inverting op amp. Surely the same "common mode failure" would apply?*

## A different solar hot water system experience

I was bemused to read the article in the August 2007 issue "How to Cut Your Greenhouse Emissions Part 2"; bemused because my experience with solar hot water is so different.

I happen to live just inside the tropics in the light green-shaded area in the map on page 10, the 75-80% zone. Two years ago I had a solar hot-water system installed at home when the aged electric system gave up the ghost. I opted for a marginally larger capacity model than the minimum recommended, as the additional cost was less than 10% at the time.

I also opted to move from off-peak electricity, with its minimum monthly charge, to standard tariff (costs more per kWh but no minimum charge) and only switch on the booster when needed. There's no reticulated gas supply here, so gas boosted wasn't an option.

Having now lived with solar hot water for two years, I can report on how often I've had to switch on the electric booster. The answer is once during winter in 2006 for two hours, and twice during winter 2007 for four hours total. We had only one lukewarm shower experience during those two years due to my not turning the booster on early enough.

The only behavioural modification for the household, post solar, was evening rather than morning showers. Cold water washing was already the norm. Do I recommend solar hot water to friends and neighbours? Of course! And No, I don't work in the plumbing or solar hot water industries.

**Ross Dannecker,**
**Rockhampton, Qld.**

## LEDs must surely replace incandescent lamps

Like many people, I am not impressed with the half-hearted approach of our Federal government to persuade us that it would be a good idea to substitute CFLs for incandescents in our homes. CFLs are a lot

### Toyota's sensible solution for speedo calibration

It has been a while coming but like all good things, it was worth the wait. Since my letter in the February 2007 issue on the major speedo error in my Toyota Yaris, Toyota has recently fitted it with a new instrument panel.

I recently spent 1.5 hours checking the new speedo at the same location as the original test. Several runs were made on the near perfectly straight 8km section of road. Speeds tested were 60km/h, 80km/h and 100km/h.

The test regime was to drive for about one kilometre at the steady indicated speed on the speedo, before taking a photograph of the GPS, for each speed range tested. The reason for this was to allow the GPS to stabilise for an accurate reading. The odometer was also checked over a 10km distance, as measured by the GPS.

The results were as follows:
(1) 60km/h indicated; GPS reading 57.4km/h
(2) 80km/h indicated; GPS reading 76.7km/h
(3) 100km/h indicated; GPS reading 97.0km/h
(4) Odo 10km indicated; GPS reading 9.91km

This test revealed a fixed error margin of indicated speed versus actual road speed, over all speed ranges tested. The average speed difference was slightly less than 3km/h.

It would appear that the replacement instrument panel has had a total redesign, which possibly incorporates intelligent microprocessor handling of sensor inputs relative to displayed speed, over the tested speed range.

The original instrument panel had a fixed error percentage over its tested speed range, meaning the faster the vehicle speed, the worse the error between actual road speed and indicated speed.

Both instrument panels were tested for odometer accuracy and found to be within 1% difference between indicated and the GPS over a 10km distance. The results of this test have proven that the new instrument panel has far greater accuracy than the original.

The small fixed speed reading difference between indicated and actual speeds is very acceptable and should take into account any small mechanical or tyre variations over the service life of the vehicle, and still be compliant with the relevant Australian Design Rules.

**Jack Chomley,**
**North Rockhampton, Qld.**

*Comment: what a great result. This proves that car manufacturers can produce a speedo which is reasonably accurate while still allowing for mechanical and tyre variations.*

more expensive to produce and more demanding of the Earths' resources than the humble incandescent.

But this is not to say that the time of the incandescent has not come. Indeed it has, years ago. I used my first Light Emitting Diode back in 1970. It was a tiny red spot of light, good only for indicating at that time but operated "on the smell of an oily rag" compared with other equipment. Forgive me for stating the obvious but LEDs have come a long way since then.

I can't claim to have any direct experience of the high-power LEDs but they must be on the threshold of replacing domestic lighting by now? True, they are currently much more expensive than incandescents or CFLs but that would partly be offset by their durability. My current 100W reflector lamps are now over $4 a pop (pun intended), which happens fairly regularly). Mass production on the scale required to replace our current lighting must surely bring the price of


## Atmel's AVR, from JED in Australia

**JED has designed a range of single board computers and modules as a way of using the AVR without SMT board design**

The AVR570 module (above) is a way of using an ATmega128 CPU on a user base board without having to lay out the intricate, surface-mounted surrounds of the CPU, and then having to manufacture your board on an SMT robot line. Instead you simply layout a square for four 0.1" spaced socket strips and plug in our pre-tested module. The module has the crystal, resetter, AVR-ISP programming header (and an optional JTAG ICE pad), as well as programming signal switching. For a little extra, we load a DS1305 RTC, crystal and Li battery underneath, which uses SPI and port G.
See JED's www site for a datasheet.

### AVR573 Single Board Computer

This board uses the AVR570 module and adds 20 An./Dig. inputs, 12 FET outputs, LCD/Kbd, 2xRS232, 1xRS485, 1-Wire, power reg. etc. See www.jedmicro.com.au/avr.htm

### $330 PC-PROM Programmer

This programmer plugs into a PC printer port and reads, writes and edits any 28 or 32-pin PROM. Comes with plug-pack, cable and software.

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## Mailbag: continued

### Aeolian radio and the Orchestrelle Company

I work in the piano industry and know the Aeolian name very well. They also made pipe organs and they owned the name "Pianola" which like "Rollerblades", "Thermos", and "Esky" (possibly today also "iPod") became a household name.

I was wondering whether the name quoted under the radio picture on page 95 of the August issue is correctly spelled. Orchestrelle was the name associated with pianos and music sales as far as I can tell. Would you like to check this? Similarly, Beale in Sydney made radios and pianos.

The piano serial number reference book I use shows Orchestrelle as a UK company along with Weber which was also associated with Aeolian. There used to be an Orchestrelle music retailer in Melbourne, as there was Palings and Nicholsons in Sydney. Many of these shops sold radios, records and musical instruments.

Some older readers may remember Melbourne stores Suttons, WH Glen, Carnegies, Christies and Maples. It is possible that some of these music instrument retailers could have sold radios too.

**Paul Smith,**
**Albert Park, Vic.**

*Comment: we referred this question to the HRSA and they have informed us that the company name was Orchestrelle.*

LEDs down considerably.

I would like to see some comparisons between incandescent, CFLs and LEDs, both in terms of end user cost, depletion of earth resources and disposal problems.

**Brian Critchley,**
**Elanora Heights, NSW.**

*Comment: we have no doubt that LEDs will eventually replace many incandescent lamps used in domestic lighting, as they already have in cars.*

### Adaptive Turbo Timer may be unnecessary

In your August 2007 article, it states, "If your car has been running, it is vital to allow the engine to idle for a few minutes before switching off".

This statement would have been correct in the 1970s. In the early 1980s, automotive turbochargers were fitted with water jackets around the rear bearing of the turbocharger. This is often referred to as water cooling which is not a good name for it, as it gives the impression that the "water cooling" keeps the turbocharger cool while the engine is running. This is not the case. The oil keeps the bearings and shaft lubricated and cool while the engine is running. The turbine shaft temperature is around 200°C while running.

In the very early days (pre water cooling), the engines were idled so the engine oil could take away the heat of the turbine wheel. If you turned the engine off after hard work, the temperature of the shaft would be so high that the oil would burn and leave a layer of carbon on the bearings and the bearing housing. If you repeatedly shut the engine down while hot, the bearing area would coke up with burnt oil.

In the 1970s, Buick fitted turbochargers to their motor vehicles. They had over 50% turbocharger failure rate in the warranty period, so a solution was needed. Water-cooling was the answer and it reduced the failures to fewer than 2%.

The water-cooling does its work after you turn the engine off. As the heat from the turbine wheel and turbine housing soaks into the bearing area, the water is heated and starts to rise. This pulls cooler water from lower in the cooling system. The process is called "thermo siphoning". Over about a 20-minute period, the cooling system turns over and keeps the shaft and bearing temperatures to less then 200°C. After this, the temperature drops away.

The only time it is recommended to idle a turbocharged engine is where

## Speedo calibrations & ADR specification

I agree with your editorial comment in the August issue (page 5) that "it may be time for the ADR speedo regulations to be updated".

It might seem odd for an electronics magazine to be discovering solutions to problems in the automobile industry but often people working in any industry stand too close to the trees to see the forest and solutions to problems are discovered by people in other industries.

I think your seemingly casual comment is an example of this phenomenon and that your analysis leading to the comment is much more significant and important than you realise yourselves.

Only a few years ago, I would have agreed with the comments by Warwick Woods and Max Williams in the Mailbag pages of the September issue. However, a phenomenon that was little more than a curiosity then has become a problem now because of the more or less random coincidence of several otherwise unrelated changes.

Firstly, the police are enforcing speed limits more diligently and more precisely. In the olden days, it was more or less common knowledge that the police set their equipment to allow a relatively large margin. While they did that, it was relatively unimportant that our speedos were poorly calibrated.

Secondly, speed cameras have become commonplace. Thirdly, many of us use our cruise control to help us to keep within speed limits even though the cruise control in most vehicles wasn't and isn't designed to do that.

Max Williams might be interested to note that Mercedes offers at least three levels of "cleverish" cruise control: the C-series has "SPEEDTRONIC" which has some speed-limiting functions; the E-series can be fitted with "DISTRONIC" which can maintain a safe distance behind a vehicle in front; and the S-series can be fitted with "DISTRONIC-PLUS" which can do the tricks demonstrated on the SBS TV program "Top Gear".

Fourthly, in modern vehicles, most clever functions are implemented electronically and the costs that concern Warwick Woods are mostly artefacts of what the lawyers and accountants think the market will pay. While only one manufacturer offers accurate calibration, they can and will charge a premium but once it becomes commonplace, it will also become affordable.

Max Williams asks us to respect the work of the people who prepared the current ADR regulations. I agree that we should do that. We should also ask them to keep doing good work and to prepare new regulations that recognise the changes since the old ones were prepared.

**Keith Anderson,**
**Kingston, Tas.**

you have been working the engine very hard and have to stop the car quickly (eg, flat tyre on the highway while towing a heavy load). In a case like this, it is recommended that you idle the engine so you do not shock the cooling system. If you are towing on the highway and come to a town, you can turn the engine off without idling, as you would have slowed down at the city limits.

The oil used is very important for turbocharger life. You want an oil that is designed for the high temperatures around the rear bearing. The best advice is use the best synthetic oils and forget the timers, as they do nothing on a water-cooled turbocharger that the water-cooling already does.

**Ray Hall,**
**Ray Hall Turbocharging,**
**Cairns, Qld.**

*Comment: the quote "If your car has been running, it is vital to allow the engine to idle for a few minutes before switching off" is a misquote from the article in the August issue. The actual statement made was "If your car's turbocharger has just been running, it is vital to allow the engine to idle for a few minutes before switching off".*

*Consequently, the Adaptive Turbo*

### GPS-disciplined oscillator stability

The idea that phase-locking an oven-controlled crystal oscillator (OXCO) to the 10kHz output of a Jupiter GPS timing receiver is a useful thing to do is an illusion (as referred to on page 98, SILICON CHIP, August 2007). The 10kHz output is phase-modulated (more of a jerk than smooth modulation) every second to keep it in sync with the next PPS output pulse. This behaviour is well-documented in the data sheet if it is read carefully.

Between phase jerks the stability of the 10kHz output is no better than that of the receiver's crystal oscillator. The short-term stability of this 10kHz output is no better than that of the PPS output. The same time loop bandwidth is required when locking to the 10kHz or PPS outputs, to achieve equivalent performance.

The fact that a number of people have made the same mistake in believing the 10kHz output has high short term stability doesn't change the conclusions.

Measuring the short-term stability of any such GPS-disciplined standard is relatively simple as their short-term stability is so bad. All you need is a low-noise stable OCXO like an FTS1200 (or selected HP/Agilent 10811 or similar) to measure the instability for measuring times from 1-100 seconds (1000 seconds or more with a good FTS1200 (or a good 10811) and a high resolution counter.

If you want to measure the Allan variance, then the type of counter used is important. A resolution of 1 part in $1^{10}$ is fairly easy to achieve. With a more elaborate set-up, a resolution of $1^{14}$/averaging time can be achieved, however OCXOs locked to the 10kHz output of a Jupiter GPS receiver are so unstable such high-resolution techniques are not necessary. The SILICON CHIP GPS reference will have an even worse instability for such averaging times so that this should be relatively easy to measure. Even an HP5370A/B can achieve a resolution of around 2E-11/averaging time.

**Bruce Griffiths,**
**Hamilton, NZ.**

*Timer does just what is required and that is to keep the engine running when necessary, straight after turbo boost usage. This provides the best form of turbo cooling because when the engine is running the turbo is cooled by the oil pumped through the bearing and a separate water-cooling system (if fitted).*

*Alternatively, without the Adaptive Turbo Timer, if the engine is switched off when the turbo bearings are very hot, the water and oil cooling are also effectively stopped. Whether to run the engine after turbo use should be decided according to the car manufacturer's recommendations.*

### Suspect sensor design in tank level meter

It's good to see some more articles that promote environmental change, namely the Tank Water Level Indicator in the July 2007 issue of SILICON CHIP. I have no qualms about the design in general; it is a novel way to achieve the task.

The thing I was puzzled with was the use of the 555 to drive the "critical" LED. This could have been done more simply with a 2N7000 FET and as such, the zero gate current would not light the last red LED and all would be happy! However since the 555 has been installed, wouldn't it have been a wise move to make the 555 an astable and actually flash the critical LED?

However, I do have a problem with the water level sensor. The method using the resistance of the water is fine except for the use of the enamel wire. Now I don't know what it would be like at these low voltage levels but enamel wire used in electric motors, alternators, transformers, inductors, etc, definitely doesn't like the presence of moisture. I would imagine that the enamel insulation on the wires inside the pipe would only last a few months and then the calibration would go up the spout!

The only suggestion that I have here is that the holes in the pipe where the wires slip through be sealed with silicone or equivalent suitable sealer (difficult task to get perfect). The bottom of the pipe should then be sealed with the manufacturer's blocking plug and the pipe then submerged in the tank to test for leaks. This will be difficult because the pipe will now want to float!

However, if this is achievable, the pipe can then be filled with say castor or olive oil, something not harmful to humans. The top would need to be covered to prevent water washing the oil over and insects making a mess. The oil level in the pipe would need to be just a little higher than the water level as oil is lighter than water. Alternatively, the pipe could be filled with epoxy or a safe grease once the circuitry was thoroughly tested. I'm not sure what expanding foam is like either although it is messy to work with. Any of these filler ideas requires the pipe to be leak-proof before filling.

**Terry Thrum,**
**Para Hills West, SA.**

*Comment: it is true that the insulation on enamelled copper wire can fail prematurely where moisture and high voltage are involved. However, in this case, the applied voltage is extremely low, less than a millivolt.*

### Light pollution still a major problem from unshaded fittings

I do hope that the 7-inch spherical outside lights that John Denham has his CFLs in (Mailbag, SILICON CHIP, July 2007) are not of the type commonly referred to as "light bombs" by the astronomical fraternity. This type of totally unshaded light fitting allows at least half of the light to shine, uselessly up into the night sky. Not only is this a waste of energy, it also contributes to the artificial night-time sky glow which diminishes an otherwise glorious view of a starry night sky.

Please properly shade all outdoor lighting. The stars are for everyone.

**Kenneth Cooke,**
**Strathfield, NSW.**

By MAURO GRASSI

# DVD Players

## Just How Good Are They For HiFi Audio?

**CD players are now relatively expensive so are there any compromises in using a cheap DVD player instead? We collected a bunch of players and put them through their paces to find out.**

THE CLASS-A STEREO Amplifier described in the May to September 2007 issues is an ultra-low distortion amplifier suitable for demanding applications. At $599.00, it's not cheap to build but that's a price many people are prepared to pay to achieve excellent performance.

By contrast, the prices of DVD players (most capable of playing almost any format you can think of) have dropped dramatically. As a result, you may be tempted to use such a player to listen to your CD collection through the Class-A amplifier, particularly if your CD player is old or "on the fritz".

Part of the problem is that dedicated CD players are no longer cheap to buy. Nor are they as readily available as they once were. To buy one, you now have to go to a hifi shop and the prices generally start around $400.00.

So how well do cheap DVD players perform as far as sound quality is

| Equipment | Power Supply | Supply Type | Type | Signal Level | SNR (10Hz to 22kHz) | SNR (10Hz to >500kHz) | THD+N (10Hz to 22kHz) |
|---|---|---|---|---|---|---|---|
| Toshiba XM5302B PC CD-ROM Drive | External | Switchmode | CD | 1.079V | -118dB | -104dB | .03% |
| Sony CDP-XE300 CD Player | Internal | Linear | CD | 2.083V | -97dB | -75dB | .003% |
| Tevion TEV1020 DVD Player | Internal | Switchmode | DVD | 1.911V | -116dB | -105dB | .05% |
| Magnavox MDVD50 DVD Player With Tingle Terminator | Internal | Switchmode | DVD | 2.018V | -115dB | -95dB | .006% |
| Panasonic DMR-ES10 DVD Recorder | Internal | Switchmode | DVD | 2.185V | -117dB | -94dB | .004% |
| Audio World AW-8032 DVD Player | Internal | Switchmode | DVD | 1.728V | -111dB | -93dB | .006% |
| Toshiba Satellite A30 Notebook DVD Drive (Via Headphone Jack) | External | Switchmode | DVD | 0.539V | -75dB | -55dB | 0.3% |

**Table 1: typical audio characteristics of a range of equipment, as measured by our Audio Precision test set. All the players are double insulated, differing only in the type of power supply (switchmode or linear). Players with THD+N of .05% or higher can be expected to sound mediocre.**

concerned? Can cheap DVD players be used in place of much more expensive, better quality CD and DVD players? Is there a difference between CD and DVD players in terms of audio performance, even for the better quality units? We decided to find out.

## Audio Precision gear

To obtain an idea of the audio quality of a range of equipment, we used our Audio Precision Test Set to test a selection of players owned by various staff members of SILICON CHIP. The players tested included DVD players, CD players and CD ROM drives (including one in a notebook). The results are summarised in Table 1.

All players were checked using the 1kHz 0dB sinewave track from the Technics SH-CD001 CD test disc. In each case, we measured THD+N (total harmonic distortion) and SNR (signal-to-noise) ratio.

In summary, Table 1 shows: (1) the type of power supply used and whether it is inside or outside the case; (2) the RMS signal output voltage; (3) the SNR with and without audio band filtering; and (4) the distortion with audio band filtering (which is substantially better than the distortion measured without audio band filtering, especially for the switchmode equipment).

Note that although the cheap DVD players like the Tevion TEV1020 had quite good SNR figures, they exhibited relatively high distortion and audible hum. The midrange DVD players like the Magnavox MDVD50 and the Audio World AW-8032 both had better distortion figures. The more expensive DVD players like the Panasonic DMR-ES10 (a DVD recorder) also performed well, with good distortion and SNRs.

Note that all these DVD players are double-insulated with switchmode supplies and for reasons to be explained shortly, produce audible hum when connected to any earthed stereo amplifier. By "earthed" we mean an amplifier with a 3-core power flex and 3-pin plug.

On the other hand, the older Sony CDP-XE300, a CD player rather than a

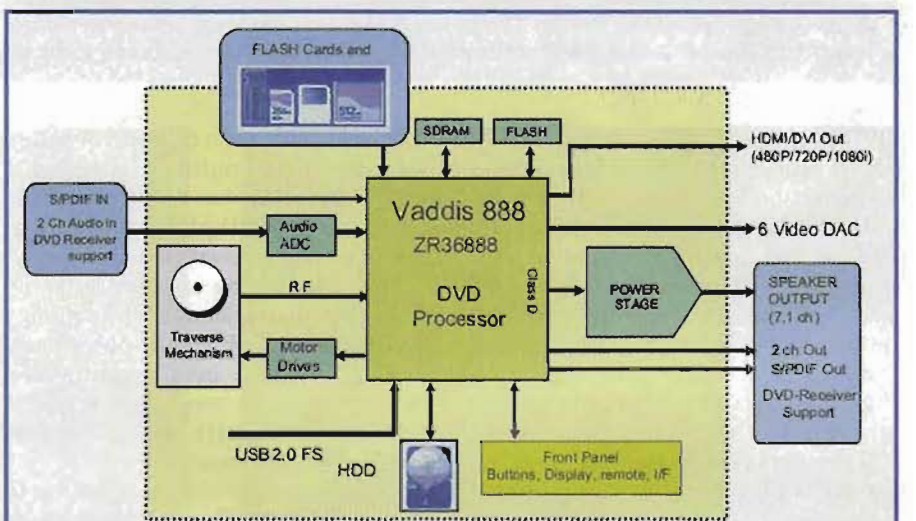
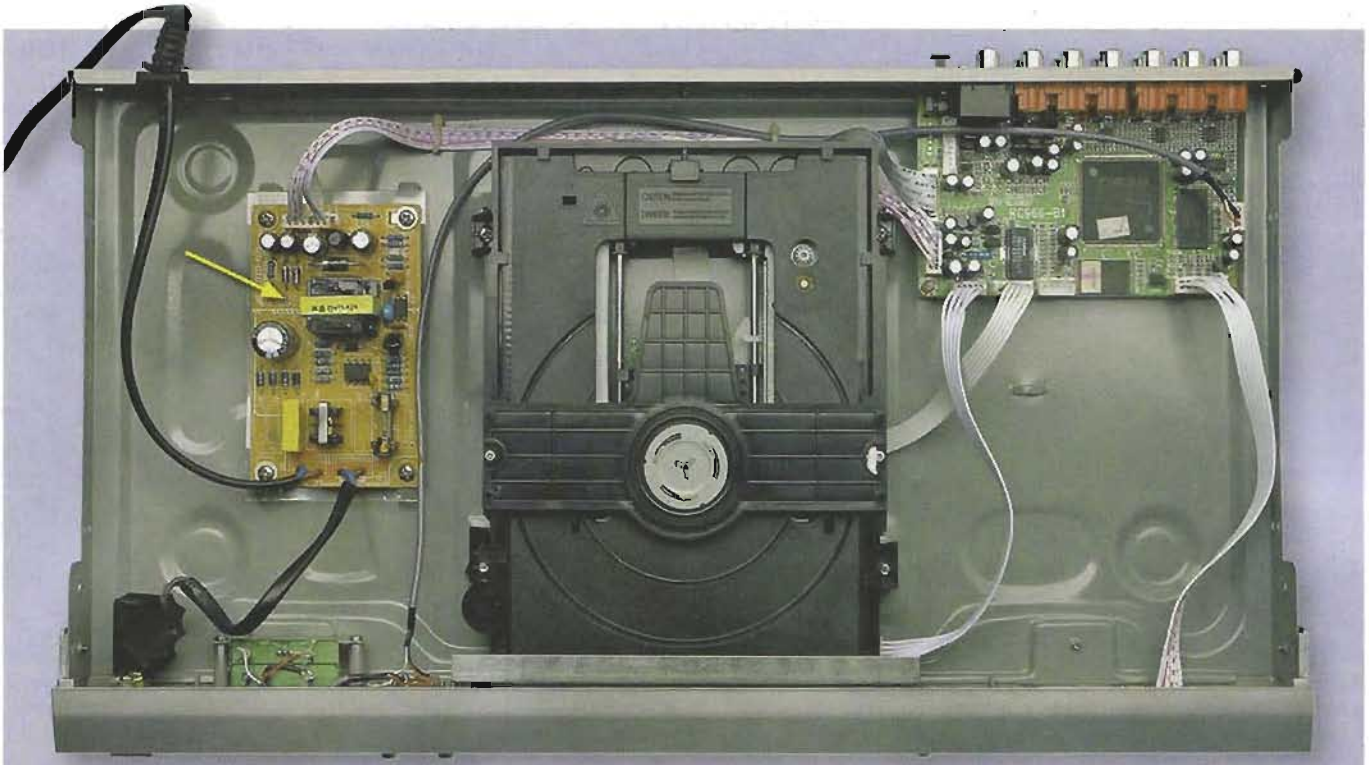



**Fig.1: block diagram of the Zoran Vaddis chip, version 888. It is a single chip solution for DVD players and DV recorders. The device includes the motor drivers, an RF amplifier and a processor, as well as various digital interfaces for external memory and external memory cards. In addition, there are input ports for video and audio, and output ports for 5.1-channel surround sound and video. There are also optional connections to hard drives (for DVR applications) and USB ports. Finally, there is a display driver, button decoding and remote control inputs. Chips of this series are found in many different DVD players.**



**This inside view of the Tevion TEV1020 DVD player shows just how few parts there are. The switchmode power supply PC board is to the left of the disk tray with the arrow indicating the high-frequency transformer.**

DVD player, uses a linear power supply. It produced no audible hum and its distortion figure was a very respectable .003%, the lowest in the group. But its SNR figure appears to be poor at only -75dB when measured with wide bandwidth (ie, >500kHz) and quite good at -97dB when measured with a 22kHz bandwidth (ie, restricting the noise bandwidth to the audible spectrum).

This deserves some explanation. Most CD players produce significant noise above the audible spectrum and this is usually filtered out during measurement to produce the manufacturer's typical specification of -96dB or better. The out-of-band noise (ie, supersonic noise) is mainly due to the switching artefacts of the CD player's DAC (digital to analog converter).

These switching artefacts will depend on the oversampling frequency used by the DAC. For example, players that use 2-times oversampling will have their main switching artefacts bunched at 88.2kHz and at the harmonics of that frequency.

The Sony CDP-XE300 appears to have a 1-bit DAC and therefore its main switching artefacts appear at around 1.1MHz. Considering that its wideband noise was only -75dB with respect to 2V, the equivalent noise signal at 1.1MHz is around 300 microvolts (300µV) or so. In other words, it is quite a significant RF noise signal to be injecting into the audio input of any audio amplifier. We will have more to say about this aspect, later in this article.

Still on the Sony CDP-XE300, it is about 10 years old and a look at its internals revealed it uses 4558 op amps in the output stages. Incidentally, these same op amps are also found in the cheap Tevion TEV1020 DVD player, although they are surface-mount types.

As an aside, where a CD player or DVD player is fitted with standard op amps, it may be possible to gain an improvement in performance by retrofitting one of the latest high-performance op amps such as have been featured in recent SILICON CHIP designs; eg, the National Semiconductor LM4562 or the Burr-Brown OPA2134.

The Toshiba CD-ROM drive and the Notebook CD-ROM drive both had mediocre performance. However, the latter's output was measured via the headphone jack, which might explain its distortion and SNR figures.

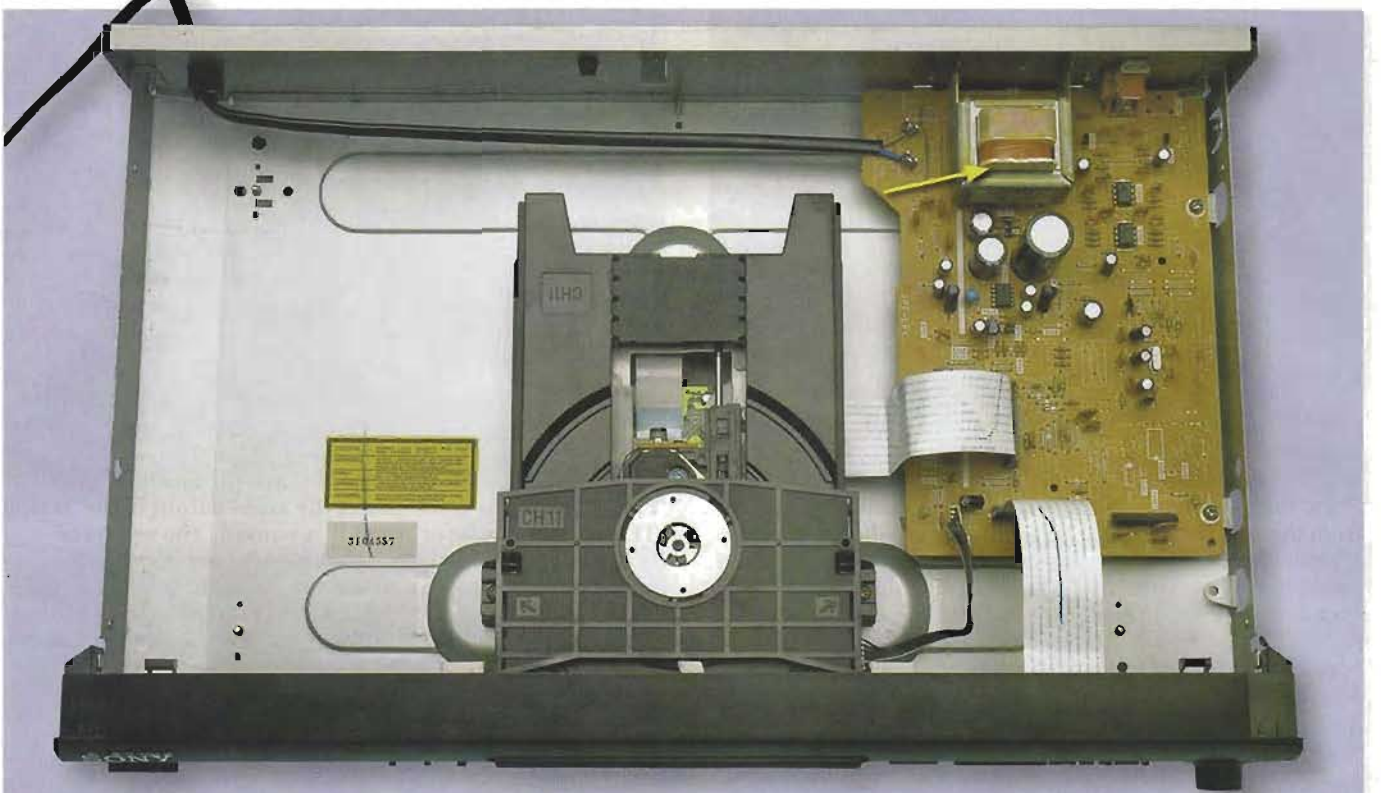
| Equipment | Case Potential Relative To Earth |
|---|---|
| Tevion TEV1020 DVD Player | 81.5V AC |
| Magnavox MDVD50 DVD Player | 115.8V AC |
| Panasonic DMR-ES10 RVD Recorder | 111.4V AC |
| Audio World AW-8032 DVD Player | 117.3V AC |

**Table 2: these are the case potentials we measured for a range of double-insulated switchmode equipment. While the voltages are perfectly safe in normal operation, they can give you an electric shock.**

## DVD player problems

DVD players present two problems as far as their audio performance is concerned. The first is that they always deliver a video output signal, even when playing CDs. This can introduce high-frequency noise into the audio signal and although this may not be audible, it can degrade the signal-to-noise ratio.

A more serious problem is the audible hum injected when a DVD player with a switchmode power supply is connected to an earthed amplifier. These days many, if not all, CD players also have switchmode supplies and so they have the same problem.



The Sony CDP-XE300 CD Player has a linear power supply with a conventional mains transformer (arrowed).

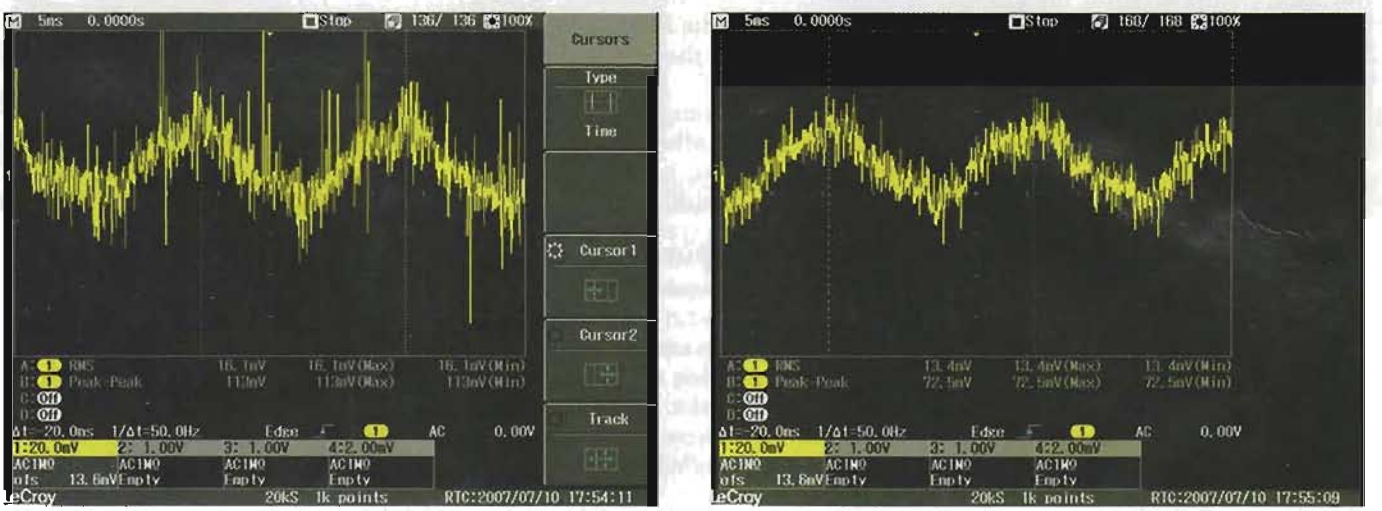



Fig.2: the yellow traces in these scope shots show the voltage across an earthed 100Ω resistor connected to the case of the Magnavox MDVD50 DVD player. The lefthand window shows the measurement when the Magnavox is floating and the installed "Tingle Terminator" is disabled, while the righthand window shows what happens when the "Tingle Terminator" is connected. The vertical scale is 20mV in both cases.

To understand the problem, we need to refer back to our article on the "Tingle Terminator" described in the July 2006 issue. This provided a simple solution for preventing the mild electric shocks that one can receive when using modern double-insulated equipment with switchmode supplies.

Because double-insulated equipment is not earthed, the equipment's case can be at a large potential relative to earth. While this is perfectly safe, it can give you a mild electric shock if you touch it.

In practice, the case can sit anywhere between 80V and 120V – see Table 2. By contrast, compare the values in Table 2 with a measured case potential of just 22V for the Sony CDP-XE300, a double-insulated CD player with a linear supply.

The "Tingle Terminator" was a workaround to the shock problem. It used a 22nF capacitor to couple the case to earth, effectively removing the shocks. In fact, with the capacitor in place, the case voltage drops dramatically to anything between 2V and 5V.

The "Tingle Terminator" was designed as an add-on to existing equipment, whose installation did not require opening the case or modifying the

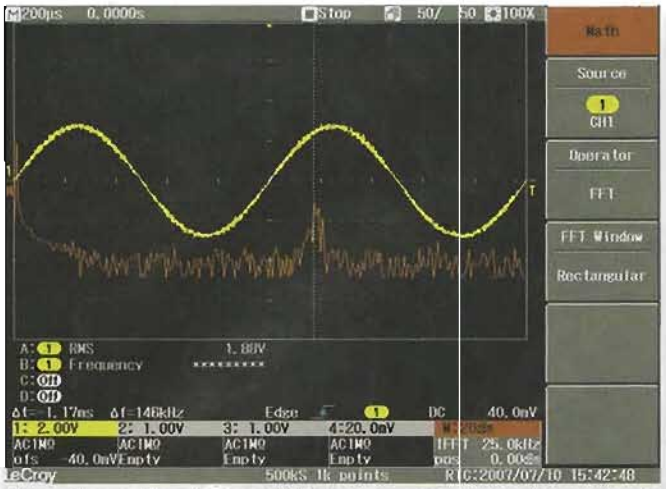



**Fig.3: the yellow trace of this scope shot shows the output from the Tevion TEV1020 DVD player for what should ideally be a clean 1kHz sinewave but which instead has superimposed noise. The red trace is the Fourier transform and this shows that higher frequencies are being superimposed on the output by the switchmode power supply. Notice the large spike at around 146kHz. Each division represents 25kHz.**

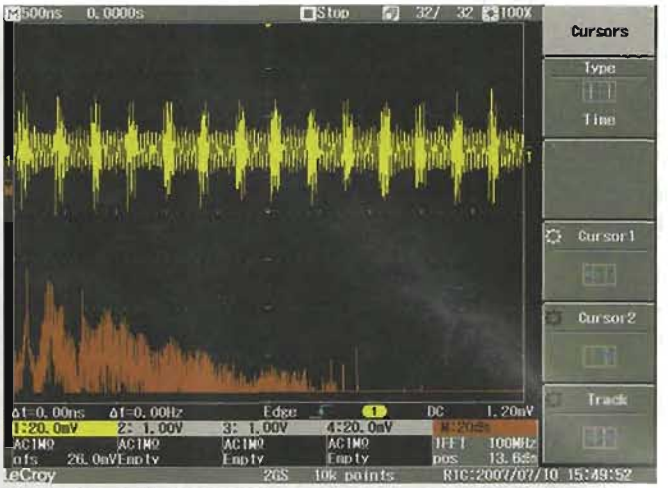



**Fig.4: the yellow trace shows the noise output of the Tevion TEV1020 DVD player when it is paused. The red trace is the Fourier transform and this indicates that a range of high frequencies are present in the signal, beginning with the first peak at 27MHz (the crystal frequency of the main IC). High signal amplitudes at higher frequencies are also present right through the FM band and beyond. Each division represents 100MHz.**

2-pin mains plug. This was done to circumvent possible issues with voiding the warranty.

Fig.2 shows the "Tingle Terminator" at work. The yellow trace shows the voltage across an earthed 100Ω 1% resistor connected to the case of the Magnavox MDVD50 DVD player. This signal is essentially the 50Hz fundamental from the mains supply. Large spikes and high-frequency noise from the digital circuits inside are also present.

Compare the top window, taken when the "Tingle Terminator" was disabled, to the bottom window, when it is enabled. In the top window, the RMS voltage is 16.1mV, meaning that around 161µA is flowing to earth. By contrast, in the bottom window, the RMS voltage is 13.4mV and around 134µA is flowing. The large high-frequency spikes have disappeared and the current flowing to earth has dropped by 17%, yet the 50Hz mains fundamental is still visible. This is what produces the hum in the audio signal, even with the "Tingle Terminator" installed.

Therefore, although the "Tingle Terminator" may be effective at removing the risk of shocks, it is not useful for removing the audible hum.

## Switchmode power supplies

The power requirements of a typical DVD player are +3.3V and/or +5V for the digital system and ±12V for the op amps on the analog side.

For example, the Tevion TEV1020 DVD player has a switchmode supply that produces ±12V for three 4558 op amps plus a +5V rail for the digital circuitry. This circuitry is based on a single Zoran Vaddis-series chip (see Fig.1), which is a common single-chip solution for DVD players.

In older, conventional power supplies (also known as "linear" supplies), a transformer completely isolates and "steps down" the 50Hz 240VAC mains. By contrast, the output side of a switchmode supply is isolated via a high-frequency switching transformer.

While the primary side of a linear supply is quite simple, a switchmode power supply has quite a few components on the primary side of the high-frequency transformer. These typically include a dedicated switchmode controller IC, a switching device and various passive compo-

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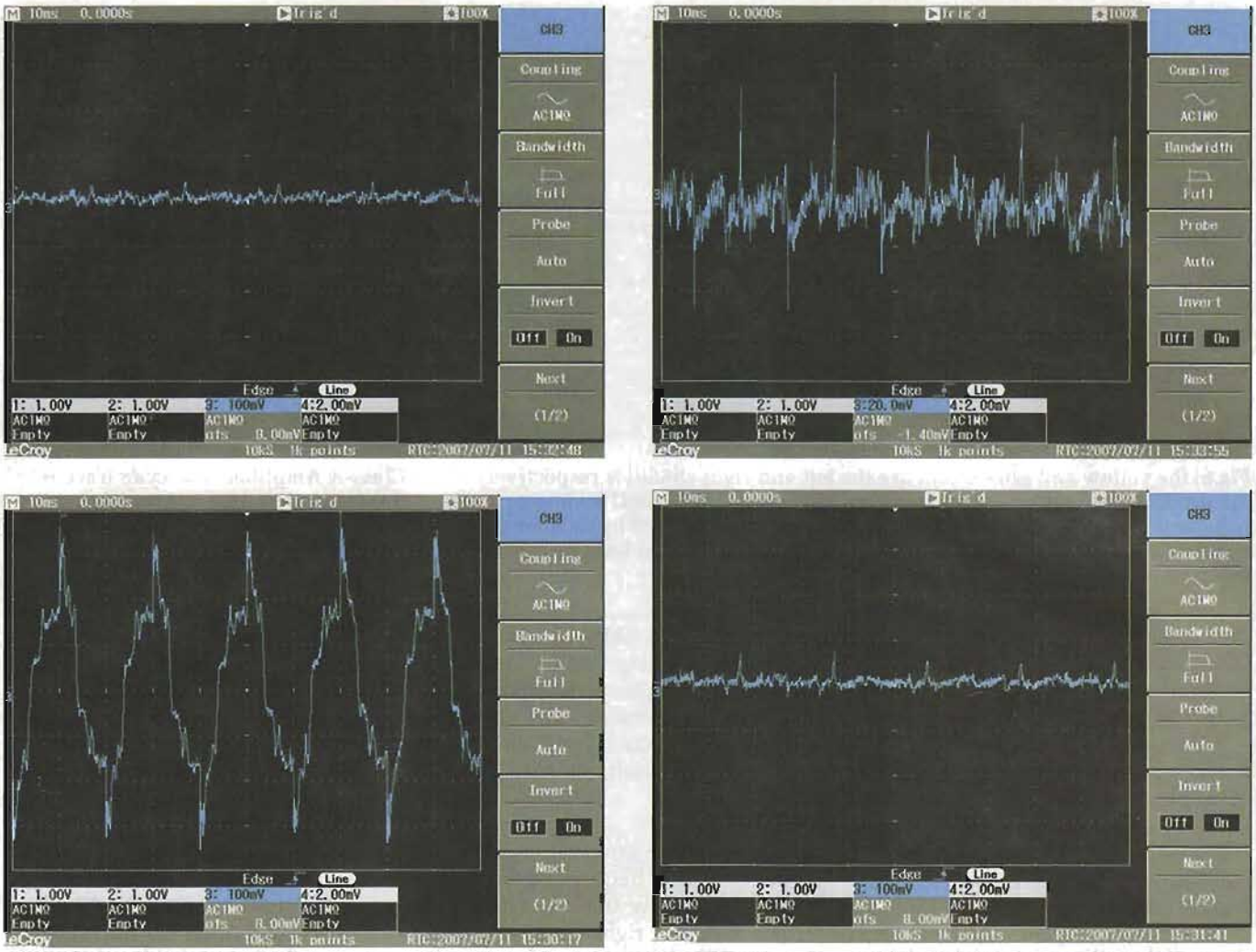



**Fig.5: the top left and top right windows show the noise output from the Class-A Amplifier at 20W into an 8Ω load, at a vertical scale of 100mV and 20mV respectively. No discernible hum is present – the waveform is simply random noise. At bottom left is the noise output of the Magnavox MDVD50 DVD player connected to the Class-A Amplifier (100mV vertical scale). In this case, a 50Hz fundamental is present and can be heard as hum. Compare this with the bottom right window, which shows the noise output of the Sony CDP-XE300 CD player in the same conditions. No audible hum is present.**

nents, including capacitors connected to ground. As the switching element is either at saturation or off, the efficiency is quite high.

## Switchmode advantages

Switchmode supplies have several advantages over linear types. They can easily step up or invert voltages, they are more efficient and they require a much smaller transformer since they switch at a much higher frequency than 50Hz.

Their high efficiency in turn equates to low heat and the smaller transformer makes them cheaper and lighter than conventional supplies. Most cheap DVD players are extremely light for this reason.

## Noise is the problem

Although switchmode supplies are efficient, they produce noise in at least three ways. First, there is ripple at the switching frequency (typically in the kHz range) in the regulated output and ripple injected into the unregulated input supply. Second, there is also radiated noise at the switching frequency and its harmonics. This noise emanates from the inductors and the high-frequency transformer.

Thirdly, as already described, the switchmode supply configuration introduces earth loops which in turn causes hum problems. What happens is that the capacitors on the primary side of the switchmode supply couple the mains input through to the signal ground, which connects to the case. As a result, when the signal outputs are connected to an earthed amplifier, current flows to the amplifier's earth, since the case of the double-insulated equipment is at a high potential.

This earth current degrades the SNR and causes audible hum in the amplifier's outputs. Note, however, that this is only a problem if the amplifier is earthed and the switchmode equipment is double-insulated (ie, not earthed).

**By the way, if you have this problem, don't even think of disconnecting the amplifier's mains earth to cure the problem. That would only serve to create a potentially fatal situation in the event of a fault in the amplifier.**

Unfortunately, the noise problem doesn't end there. Since a DVD player also produces a video output signal, the noise component of its audio signal is potentially of a much wider bandwidth than for a dedicated CD player.

To see how bad it can be, we meas-

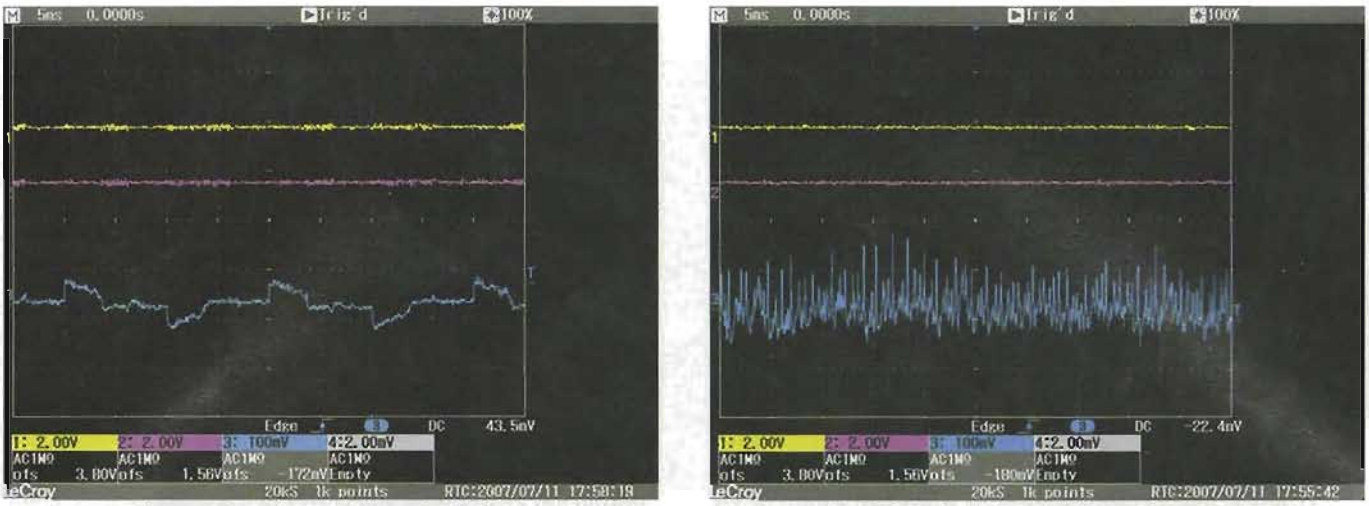


**Fig.6: the yellow and pink traces are the left and right channels respectively of the Class-A Amplifier. The cyan trace is the distortion signal produced when the Magnavox MDVD50 DVD player, connected through the Class-A Amplifier, is paused. In the lefthand window, the Magnavox is powered by its internal switchmode supply. By contrast, in the righthand window, the Magnavox is powered by an external linear supply. Notice that the 50Hz hum present in the lefthand trace has disappeared in the righthand trace.**

ured the Tevion, the worst in our group of DVD players. First, we measured the radiated noise from its switchmode power supply, as shown in Fig.3.

As shown, the yellow trace is the audio output from the right channel of the Tevion TEV1020 DVD player. It should be a clean 1kHz sinewave but it has a lot of superimposed noise. The resulting measured distortion figure is high at .05%, as indicated in Table 1.

Using a pick-up loop placed near the switchmode supply of the player, we measured the induced current produced by the electromagnetic field of the high-frequency transformer. The resulting noise waveform had a frequency around 130kHz, which we assumed is the switching frequency for this model.

The red trace in Fig.3 is the Fourier transform of the 1kHz audio output and it shows a large peak at 146kHz, again close to the suspected switching frequency, confirming that there is noise being injected from the power supply into the audio output.

## It gets worse

It gets worse, however, when we look at the higher frequency noise – see Fig.4. The yellow trace is the noise output from the right channel of the Tevion DVD player when it is paused, while the red trace is the rectangular Fourier transform. The latter has its first large peak at 27MHz, which is the fundamental crystal frequency of the main IC. Large peaks follow all through the FM band, with smaller peaks then following as the frequency increases right up as far as 675MHz – that's right up in the UHF TV bands!

As a result, when connected to an FM/AM stereo receiver in order to play a CD, not only can it blot out all AM radio reception from that receiver, but it can blot FM radio reception as well.

In addition, the same DVD player can produce audible high-frequency noise through the speakers of the amplifier it is connected to. We don't know whether other cheap DVD players have the same problem but given that they probably use the same Zoran LSI chip, many equally cheap DVD players could easily be just as bad or even worse.

| Equipment | Power Supply | Switchmode | Signal Level | SNR (10Hz to 22kHz) | THD+N (10Hz to 22kHz) |
|---|---|---|---|---|---|
| Sony CDP-XE300 CD Player | Internal | No | 12.65V | -77dBr | .003% |
| Magnavox MDVD50 DVD Player | Internal | Yes | 11.28V | -82dBr | .009% |
| Magnavox MDVD50 DVD Player | External | No | 11.28V | -94dBr | .012% |
| Tevion TEV1020 DVD Player | Internal | Yes | 12.65V | -75dBr | .051% |
| Tevion TEV1020 DVD Player | External | No | 12.65V | -100dBr | .052% |

**Table 3: the audio performance of various players connected through the 20W Class-A Stereo Amplifier. All are normally switchmode powered except the Sony CD player. The table also shows the difference to the SNR when an external linear supply is substituted for an internal switchmode supply in the two DVD players. The signal level of 12.65V represents 20W into 8Ω load.**

## The hum problem

Let's now go back to the main issue, which is audible hum. Of all the players tested, only the Sony CDP-XE300 CD player (ie, the player with the linear power supply) exhibited a quiet output signal when it was paused while connected to the Class-A Stereo Amplifier. The other players, especially the cheap DVD players like the Magnavox MDVD50 and the Tevion TEV1020, all exhibited audible mains hum under the same circumstances.

Take a look now at Fig.5. The two top windows show the noise output of the Class-A Amplifier when the inputs are shorted with a 1kΩ resistor. Two different vertical scales are shown: 100mV/div for the left window and 20mV/div for the right window. No hum can be seen in the signal nor can any hum be heard through headphones.

In the bottom left window, the cyan trace shows the noise output of the Magnavox MDVD50 DVD player when it is paused while connected to the Class-A Amplifier. Hum is now clearly visible in the form of a 50Hz fundamental sinewave and this comes from the mains. The vertical scale is set at 100mV.

Now compare this with the noise output of the Sony CDP-XE300 CD player, shown bottom right at the same vertical scale. No discernible hum is present, nor can any be heard.

To verify this, we connected one headphone channel directly across the amplifier's speaker terminals, using the circuit shown in Fig.8. This further confirmed that the switchmode DVD players produced hum while the linear supply CD player did not.

Not satisfied with this, we performed yet another test – see Fig.6. The yellow and pink traces are the left and right channels respectively of the Class-A amplifier. The cyan trace is the distortion signal produced when the Magnavox MDVD50 DVD player is connected to the Class-A Amplifier and paused.

There's an interesting twist here though. In the top window, the Magnavox was powered by its internal switchmode supply. However, in the bottom window, the switchmode supply was disabled and the Magnavox was instead powered by an external linear supply that we patched in. Notice that the 50Hz hum that's present in the top trace has disappeared in the bottom trace!

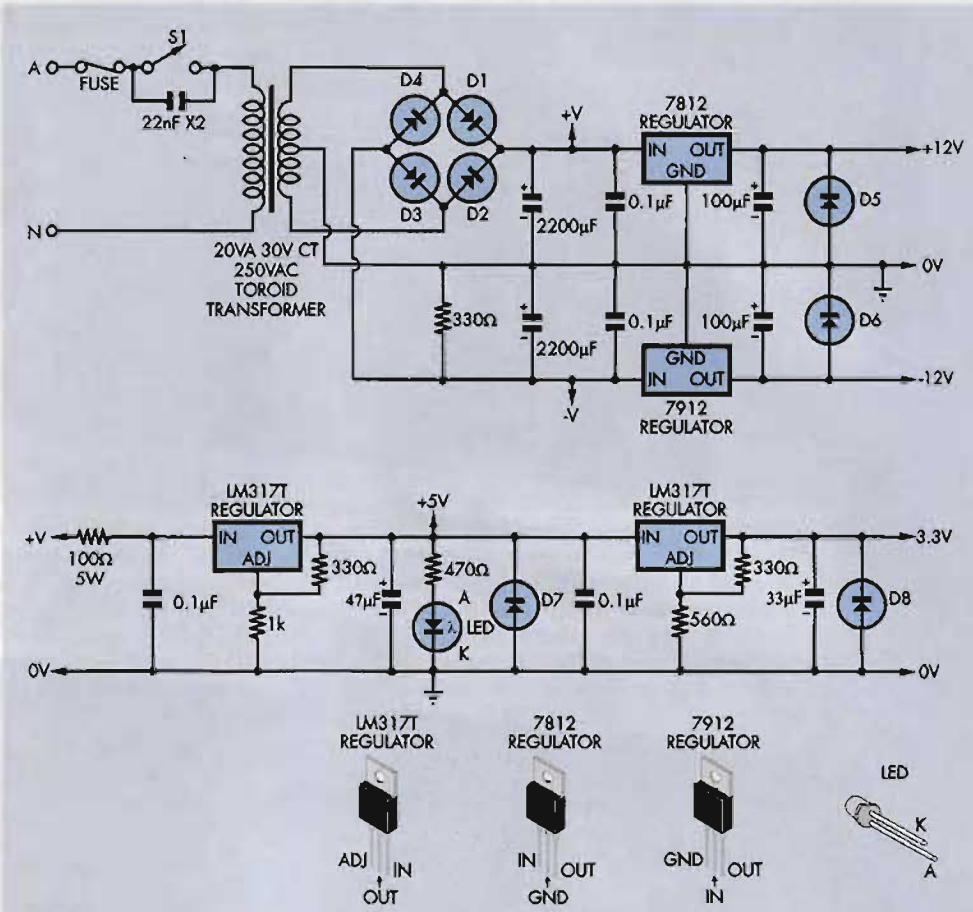



**Fig.7: this diagram shows the linear power supply we developed to replace the switchmode supply in the Tevion & Magnavox DVD players.**

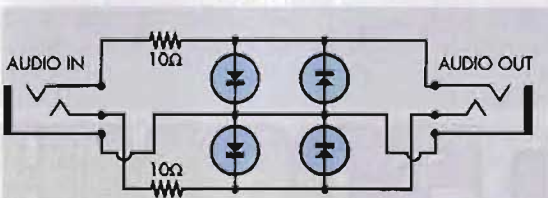



**Fig.8: this circuit can be used to protect stereo headphones that are connected directly to the outputs of a stereo amplifier. The 10Ω resistors limit the current, while the four diodes limit the maximum voltage across each earpiece to about ±0.6V.**

## Audio performance

Finally, we measured the audio performance of the Magnavox MDVD50 DVD player, the Tevion TEV1020 DVD player and the Sony CDP-XE300 CD player when connected to the Class-A Stereo Amplifier. Their SNR and THD+N measurements are shown in Table 3.

We measured the SNR of the Class-A Amplifier at 20W into 8Ω to be -107dB with 1kΩ shorting jacks. Table 3 shows that changing the switchmode supply to a linear one improved the audio performance of the two DVD players. For example, the Tevion TEV1020 DVD player had a SNR of -74dB when connected through the Class-A Amplifier (at 20W into 8Ω) when using its internal switchmode supply. However, this improved by some 25dB to -99dB when it was powered by an external linear supply!

## Conclusion

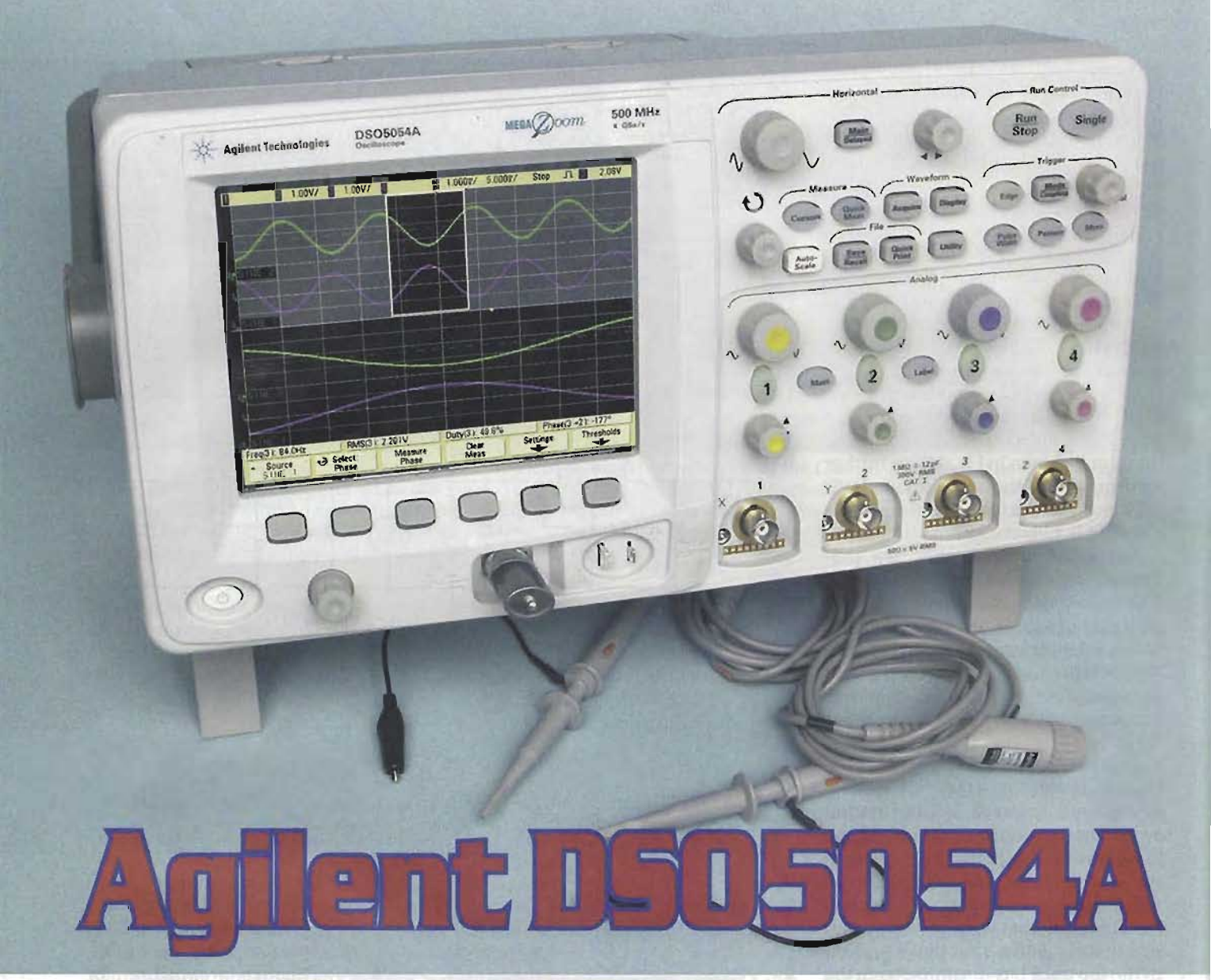
These tests lead us to just one conclusion. If you want the very best audio performance from your hifi system, then a dedicated CD player with a linear supply is the only way to go. DVD players may cost a lot less but their switchmode power supplies introduce audible hum when connected to an earthed audio amplifier.

Even so, a cheap DVD player may be an attractive proposition for playing audio CDs in non-critical situations. This particularly applies if your listening position is far enough away from the speakers to render the hum inaudible.

Substituting an external linear supply for the internal switchmode supply certainly gets rid of the hum. In fact, we went so far as to design a suitable linear supply that could be retrofitted to cheap DVD players.

In the end, however, we scrapped the idea – the audible hum problem was not sufficiently bad to warrant the extra cost of the linear supply. It also does nothing to improve a mediocre THD+N performance.

If you want the very best, buy a good CD player. SC




# Agilent DSO5054A

## 4GS/s 500MHz 4-channel digital scope

Review by Mauro Grassi

**There are so many** different digital scopes on the market that many prospective buyers probably think they are all much the same.

Nothing could be further from the truth! Each manufacturer has a different philosophy in producing a mix of performance and ease of use, control presentation and a host of operating features.

Few digital scopes are truly intuitive to use, even to people who are very familiar with these instruments. Some have deep multi-level menus and all will have common features, which are sometimes easy to access while others can be quite difficult.

Having said that, the digital scope scene does not appear to have changed very much over the last few years, as the principal players have been slow to bring out new models.

Well, that has just changed with the release of the 5000-series digital scopes from Agilent Technologies (previously Hewlett-Packard).

We had a chance to use the top-of-the-range 4-channel Agilent DSO5054A for a few days and we came away very impressed.

For a start, it has a very simple control layout. Each vertical input channel has its own sensitivity and vertical shift controls and the knobs are colour coded to match the traces

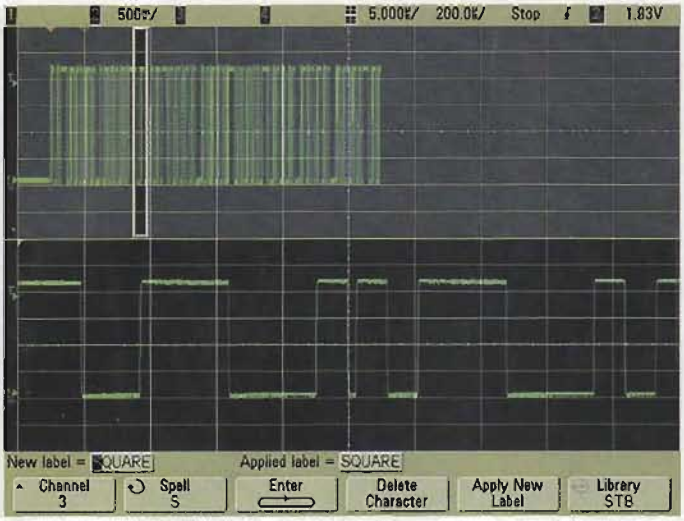



**Fig 1: the green trace in the top window shows a digital pulse train. The bottom window is the result of zooming in on the un-shaded area in the top display. The top line displays the vertical scales of the four channels, showing that only channel 2 is being used, and the timebase of 200µs/div is displayed. The top line also says that the un-shaded area in the top window, being expanded below, is 5µs/div, giving a magnification factor of x40.**

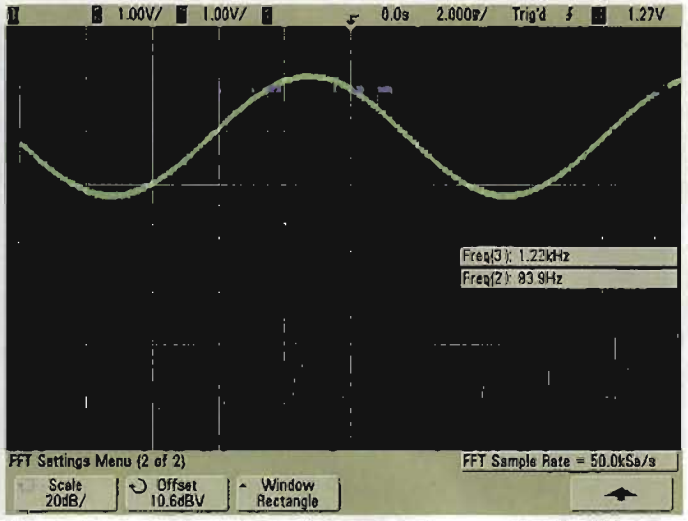



**Fig 2: the green trace is a sine wave at around 84Hz. The purple trace is a square wave at around 1.2kHz. The frequency measurements of the waves can be seen mid-right, while the FFT of the square wave is shown in grey in the bottom part of the display, showing peaks at the odd harmonics. Rectangular mode is selected and the vertical scale (in dB) and the offset in dBV can be selected. The FFT sampling rate stands at 50kS/s.**

on the screen. This means that you do not go through the annoying charade of changing the sensitivity control only to find that you have changed and shifted the wrong trace! That can be extremely annoying when you have three or more traces on the screen.

The display looks very bright and sharp. It has 256 intensity levels controlled by a knob and a high resolution XGA (1024x768 pixels) colour display that allows fine details to be seen. The intensity of the grid can also be independently controlled.

Timebase controls are immediately to the top right of the screen and there is a button to select main and delayed time-bases.

Below those are two buttons for measurement: Cursors and "Quick Meas" and below those again a pair of buttons for Save/Recall and printing (or dumping to USB flash drive) screen grabs.

Each BNC input has auto-sensing for probes and can also provide power for active probes. Individual channels have selectable input impedances of 50Ω and 1MΩ, bandwidth limiting to 25MHz and selectable AC or DC coupling, shown by dedicated LEDs when enabled on each channel.

## The Cooks tour

Let's take a tour of some of the features of this scope. The first thing to notice is the integrat ed help provided by this scope. Pressing and holding down any button brings up a detailed on-screen message to explain its function. That applies to any of the soft buttons as well.

So there is no need to operate "blind" with this machine. It will tell you what to do (well, you do need some clues about operating scopes!) in any of 11 languages. When a knob is turned to its limit, an on-screen bubble pops up saying so. When a button or knob has no current function and it is pressed, the scope again tells you.

Displaying a signal is easy, as one of the nicer features of this scope is the "Auto-Scale" feature. This is found in most modern scopes, yet this scope is exceptional in this regard.

Simply connect the probe to your signal source and press the "Auto-Scale" button. Both the triggering mode and the vertical and horizontal scales are quickly changed to accommodate the active waveforms on the screen in an optimal viewing configuration. Waveforms that are not present are automatically disabled from being displayed.

By the way, Auto-Scale works on all active channels and it neatly separates the traces on the screen. Any signal with a peak-to-peak amplitude of at least 10mV and a frequency above 50Hz is automatically displayed.

Auto-scale can also be undone at the touch of a button to return to the previous setup! Moreover, the scope does a good job of selecting automatic settings and waveforms can be grounded or centred.

The former displays the waveform with its lowest point corresponding to the bottom edge of the screen, while the cen-

## Specs at a glance

| | |
|---|---|
| Input channels: | 4 |
| Analog Bandwidth: | DC to 500MHz |
| Sampling Rate: | 4GS/s half channel or 2GS/s for each channel |
| Memory Depth: | 1Mpts half channel or 500kpts for each channel |
| Vertical Sensitivity: | 2mV/div |
| Vertical Resolution: | 8bits and up to 12bits in high resolution mode |
| LCD display: | 6.3inch colour TFT XGA, 1024x768 pixels, 256 levels of intensity control |
| Weight: | 4.1kg |

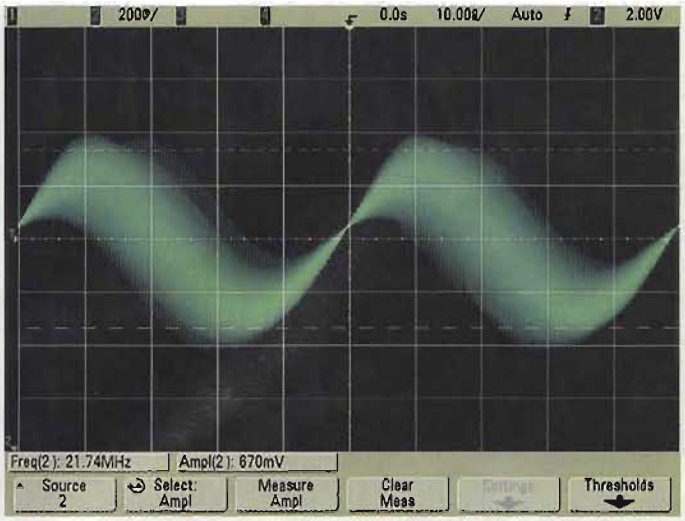



**Fig 3: the green trace shows an AM signal, with a 20MHz carrier frequency. The amplitude and frequency of the signal are shown on the bottom of the display, showing an amplitude of 670mV and a frequency close to the carrier frequency. The carrier frequency was generated by a crystal oscillator on an especially-made board used for demonstrating the scope's features.**

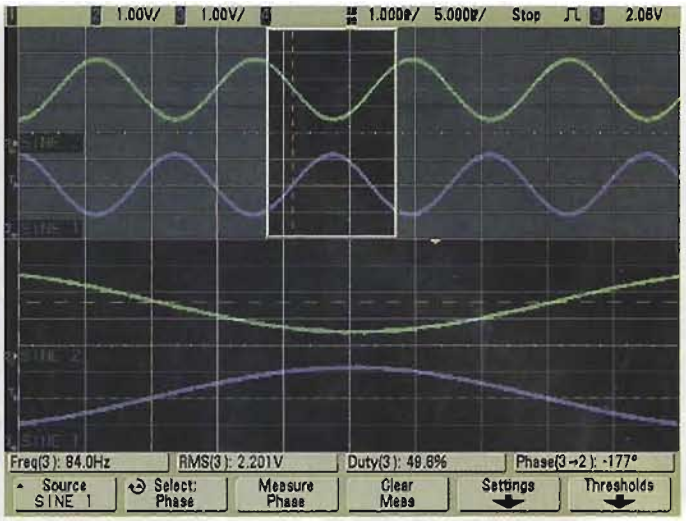



**Fig 4: the green and purple traces are sine waves, which are out of phase by 180°. The unshaded area in the top window is expanded in more detail in the bottom window. The traces are labeled by user-selectable strings. The bottom line shows the frequency of the green trace and its RMS voltage of 2.201V, its positive duty close to the expected 50% and the phase difference with the purple trace of –177°.**

tred mode adjusts the waveform to have its middle point in the centre of the screen.

The vertical sensitivity can be adjusted in either mode and while the trace is easier to find in the centred mode, this scope allows the vertical scale to be adjusted in the grounded mode and the display is regularly scaled to fit the trace in the best viewing position.

This is a very nice feature not readily found in other scopes, where changing the vertical scale often means shifting the trace off the screen!

After displaying a trace on the screen, you will probably want to do measurements. So just press the "Quick-Meas" button.

You will get a display of the four most recently selected measurements or if none have been selected, you get the signal frequency (provided you have at least one full signal cycle displayed) and the peak-peak voltage for channel 1.

Pressing one of the soft buttons (so-called "soft" because they can have many functions) brings up a choice of 23 measurements (duty cycle, rise time, fall time, RMS, standard deviation, max, min etc). You can select the measurement by multiple pressing of the same button or scrolling down through them using the illuminated knob. If that is not sufficient, you can also use cursors to measure points on the waveform. Two cursors on both vertical and horizontal scales can be selected, shown as dashed orange lines. The cursors can also operate in binary or hexadecimal modes.

For example, when sampling a digital signal in binary mode, the cursor can let you know whether the signal is high or low at any point of the waveform. This is displayed as a 4-bit binary string, having one bit for each of the four channels. This can tell you, say, that the waveform is high at 60ns from the trigger point.

Running through some of the specs, the DSO5054A has a fast sampling rate up to 4GS/s and has a deep memory of up to 1Mpts (depending on the number of channels in use).

This means you can view and store waveforms at high sampling rates for longer. It also means you can zoom in on waveforms and see finer details that you might otherwise miss. This is important for any demanding debugging application. Coupled with its fast refresh rate of 100kHz, the result is a very powerful scope.

While other scopes have deep memory modes that can be enabled when needed, this scope has deep memory that is always on, the so-called Mega-Zoom feature. While most scopes will sample at their highest rate at the fastest timebase setting, the sampling rate will drop as the timebase is stretched, simply because the onboard memory is limited.

Having a deep memory is therefore essential to sustain high sampling rates for longer periods, allowing more of the waveform to be seen at any one time.

The DS5000 series scopes have useful maths functions, including FFT (fast Fourier transform) for spectrum analysis, differentiating and integrating functions, as well as arithmetic operations.

This is the first digital scope we have seen with integration and differentiation. Integration is useful if you would like to measure the energy consumption of a circuit, for example.

Channels 1 and 2 can be added, multiplied and subtracted and the result displayed as another trace. This can be useful in many situations, not only to compare two waveforms.

If you want to know more about a waveform's frequency components, you can use the FFT function. The FFT can take its input from any of the four channels and even from the result of adding, subtracting and multiplying two of the channels!

It can operate in three modes: Rectangular, Hanning and Flat-top. Each is suited to different applications. The Hanning mode has high frequency accuracy and can be used to compare the frequency of two waveforms. The trade-off is less amplitude accuracy.

Flat-top mode is useful for high amplitude accuracy of frequency peaks, while Rectangular mode is a good all round mode with good amplitude

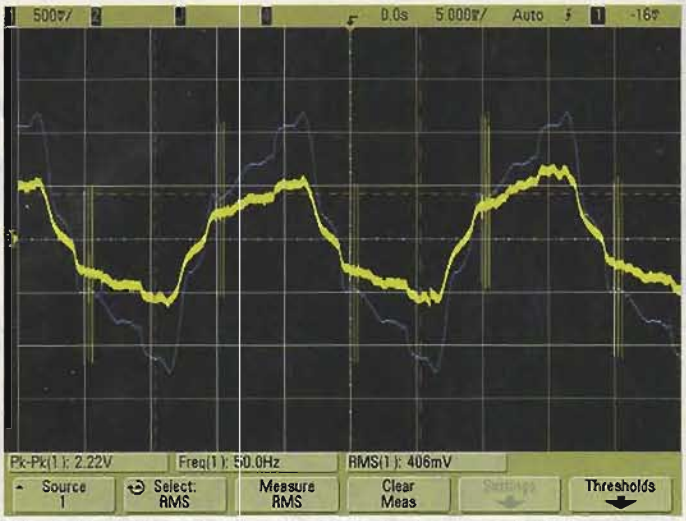



**Fig 5: the yellow trace is mains interference at 50Hz, with an RMS voltage around 400mV and peak-to-peak voltage around 2.2V. The blue background trace is a previously stored version of the same signal but with averaging applied. Stored waveforms can be recalled onto the screen and superimposed on real time signals.**

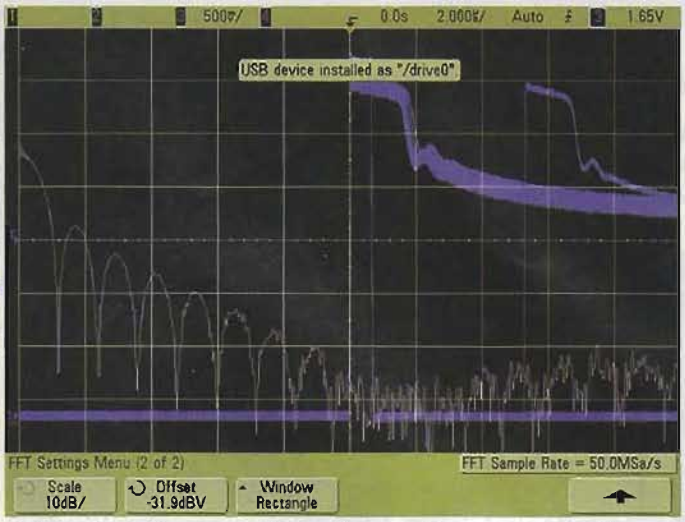



**Fig 6: the voltage waveform (in purple) across a small motor as it is switched on. Superimposed on this is its FFT (Fourier transform) showing large peaks at some low frequency harmonics, degenerating into more unordered peaks as the frequency increases. The FFT is operating in Rectangular mode and the sampling rate is 50MS/s.**

and frequency resolution. The FFT is indeed fast and this was the continuing impression we had of this scope. It is truly fast.

Pressing the 'Preset' button in the FFT menu will cause the settings to change to allow the whole spectrum to be displayed on the screen. This can be considered a kind of "Auto-Scale" feature for the FFT!

## Standard Connections

The DSO5054A has a variety of interfaces. There is the usual GPIB port, an Ethernet port, a USB device port and two USB host ports. The latter are useful for connecting a printer (allowing direct printing of the screen on compatible HP printers) and dumping screen grabs of waveforms onto a USB flash drive.

Waveforms can be labeled with an alphanumeric string. There is even a predefined library of labels with common strings like ALE (address latch enable), CLOCK, etc.

If you want a larger display, there is an XGA video output port. When connected to a large LCD monitor, the result is a good-looking display that is bright and easy to read.

Remote control of the scope is possible through Agilent's software suite, allowing waveforms to be uploaded to a computer for further analysis.

Screen grabs can be saved directly as bit maps, PNG graphics files, or exported in CSV (comma separated values) format for use in a spreadsheet.

For more advanced applications, you can program the scope using Agilent's IO Library suite.

## Acquisition & triggering

Four acquisition modes are available: normal, averaging (up to 65536 sweeps!), peak detect and high resolution.

Peak detect mode is useful for debugging applications, where fast glitches cannot be missed. In this mode, the waveform is sampled at the highest rate and maximum and minimum points are stored in memory. This is useful for seeing narrow glitches in the waveform that can easily be missed within a relatively low frequency signal, which most scopes will sample at the less than the maximum sampling rate.

This scope has advanced TV triggering modes, from the usual PAL and NTSC, to HDTV1080i/50 and generic modes for composite video signals.

As such, it will be appreciated by technicians working with the latest video formats.

The Pattern Triggering mode allows each channel to trigger on a low, high or "don't care" level, or on edge transitions.

Each channel can be defined to trigger on any of these. Pulse width triggering allows triggering on a high or low pulse of selectable width. The hold-off period for triggering can be adjusted and this controls the amount of time that the triggering circuit is delayed before it is re-armed. This allows a more stable display of complex waveforms.

We should clarify the specifications for this scope. The maximum sampling rate is 4GS/s in half channel mode. This means that only one of channels 1 and 2 can be used and one of channels 3 and 4 can be used. When all channels are used, ie in full channel mode, the maximum sampling rate drops to 2GS/s. A similar caveat applies to the memory depth.

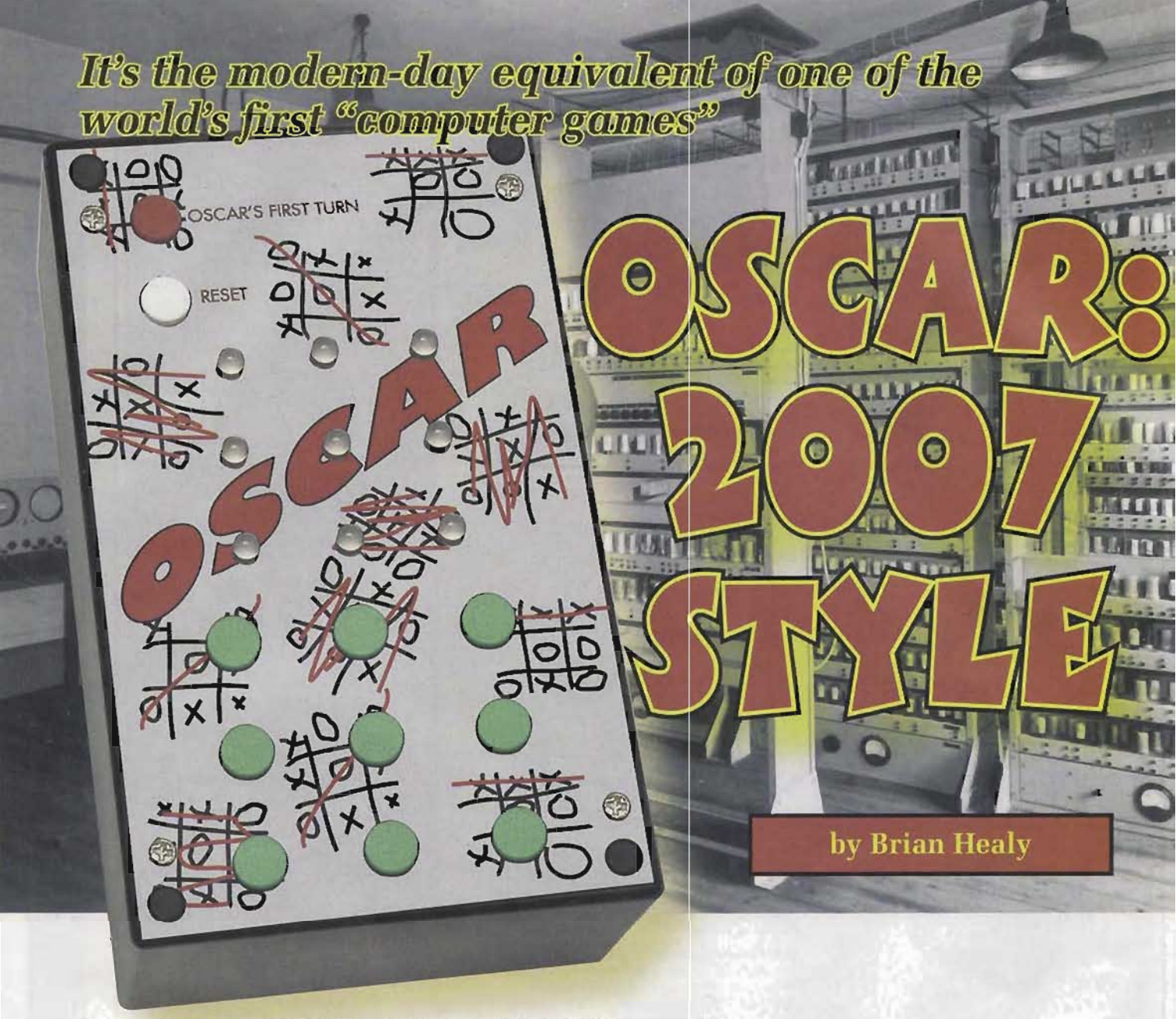
## What's the damage?

The recommended retail price of the DSO5054A is $14,231 (according to the Agilent website), which is very competitive for an oscilloscope of such specifications.

It is supplied with four Agilent 10073C passive probes with automatically detected 10:1 attenuation rated at 400V peak-to-peak CAT II, a carry case and manuals.

Agilent's software suite, including programming libraries and DLLs can be downloaded from the Agilent website. For further information on the Agilent 5000 series scopes, have a look at the Australian Agilent website at www.home.agilent.com/agilent/product.jspx?cc=AU&lc=eng&ckey=875171&nid=-35642.0.00&id=875171 or contact the Australian distributors Trio Smartcal. SC

*It's the modern-day equivalent of one of the world's first "computer games"*




# OSCAR: 2007 STYLE

by Brian Healy

**Noughts and crosses may rate quite poorly amongst young gamers of today but in the late 1960s, a machine, more often called an electronic brain than a computer, playing noughts and crosses against a human opponent, was quite a sensation.**

The first computers were built during World War II to attempt to decode German coded signals.

From this early work sprung "EDSAC" (Electronic Delay Storage Automatic Calculator) the first truly programmable computer, built at Cambridge University (UK) in 1949.

This computer, shown in the background above, was used by mathematicians for research and learning. It contained 3000 valves and consumed some 12kW of power!

History was made in 1952 by AS Douglas, a young PhD student, when he used it for another purpose: he programmed it to play noughts and crosses. The computer used a cathode ray tube to display its output, which means this was the very first video game in the world.

In the mid 1960s both Sydney and Melbourne technical museums attracted large crowds with a "computer' which played noughts and crosses against a human opponent.

In 1968, when the author was aged 24, he and a friend built a machine using 70-odd telephone relays and a uniselector to play the game.

A uniselector, by the way, is a rotary, solenoid driven, fifty position switch. They were commonly used in automatic telephone exchanges at the time and were even found in some

older exchanges until quite recently, when first solid-state devices and then microcontrollers took over. In a busy telephone exchange, the noise of the uniselectors switching back and forth following the numbers dialled on a phone perhaps ten kilometres or more away was quite deafening!

Our machine was as large as a refrigerator and about twice as heavy! We called him OSCAR and he worked very well. When you pressed a button for your turn, the machine started whirring loudly (the sound coming from the uniselector), a row of lights flashed, relays clicked in and out and finally it all stopped as it brought up its reply. It was very impressive.

We hired it out to retailer David Jones and a new shopping centre called Westfield in Wollongong (a large city south of Sydney) where it attracted large crowds.

It must be very difficult for people who did not come through that era to understand such a reaction, so I will try to explain.

**This is a Uniselector, a 50-way solenoid-driven switch. Every automatic telephone exchange used these in their thousands – now they are virtually a museum piece. The Uniselector was used as the basis for the original "Oscar" built by the author back in the 1960s.**

It was akin to the crowds who gathered on footpaths outside electrical retailers a decade or so earlier to watch that new-fangled invention, television, playing in the windows.

In 1968 very few people had ever seen a computer "in the flesh". They may have seen one in a film where typically it would be in an almost sacred situation, a series of large metal cabinets, some with large tape spools rotating and all attended by well groomed, bespectacled technicians, wearing white lab coats, hovering over it like nurses over a new born baby. What the computer actually did was a complete mystery and there was no way you were ever going to be able to get close enough to touch one.

So, if suddenly you were now able to have contact with a computer, to challenge it at a game that you un-

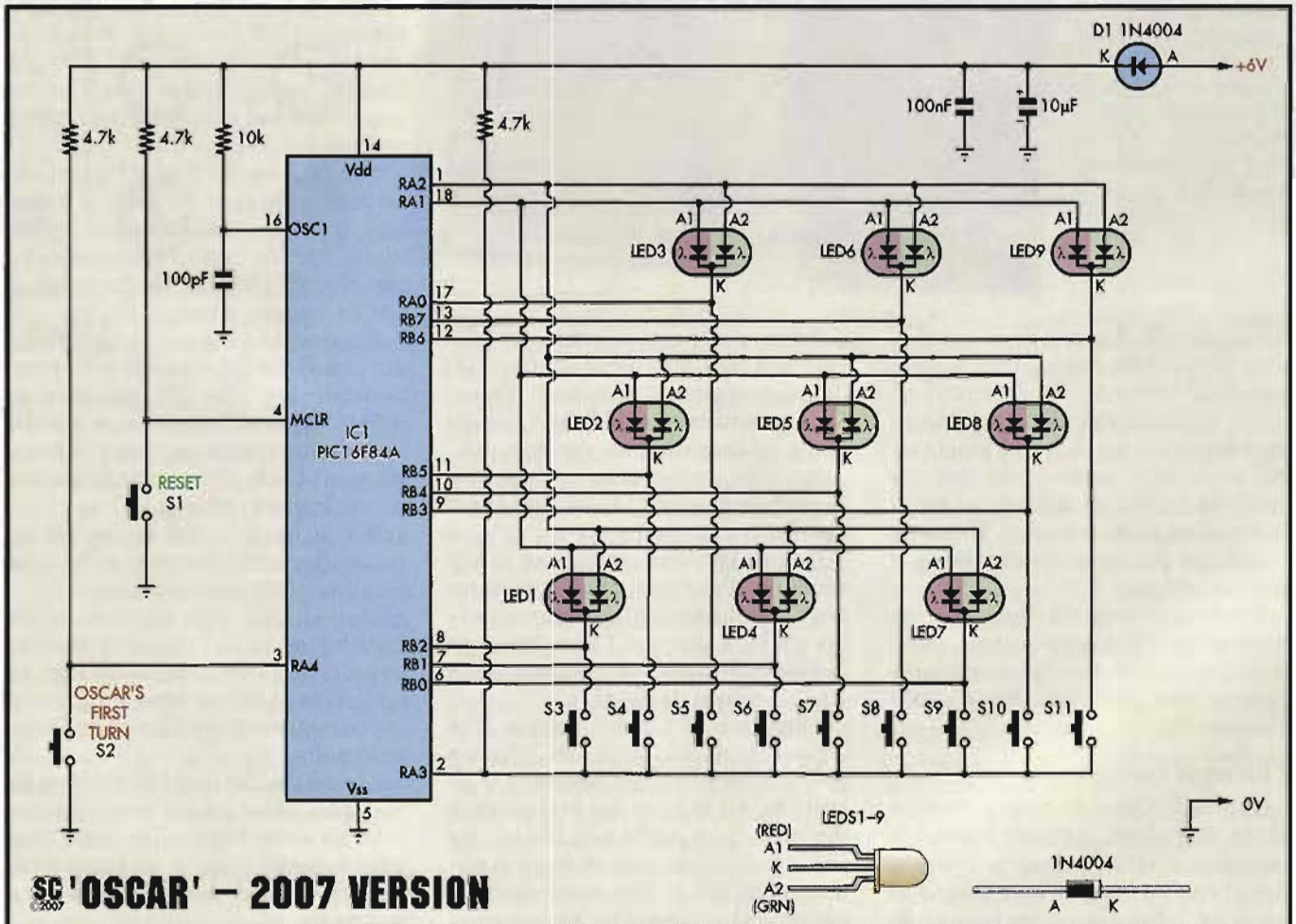



**Fig.1: not a Uniselector in sight (or even hidden!). The PIC chip does all the work of the mechanical monster of 40+ years ago – and this OSCAR is much easier to build.**

OSCAR PLAYS IT SQUARE DINKUM

challenging him in their place.

Oscar is the brain-child of Circle Electric proprietor Brian Healy, of North Wollongong, and his brother-in-law, Ian Slater.

Brian, 24, said the idea came to him about seven years ago.

"I was toying around with the circuits for about a year before I decided to build Oscar," he said.

"It took my brother-in-law and I 12 months' spare time to do it, but in the end we knew we had 'given birth' to a champion."

Since that eventful day Oscar has been beating the best of them.

If it's any consolation, Oscar can be beaten, but yesterday Brian wasn't letting on how.

● Vicki Franks, 17, of Wollongong, thought she had Oscar's measure yesterday at David Jones Wollongong store, but like so many others, she found she wasn't in the race. If you fancy your chances at 'noughts and crosses' you'll find Oscar on the first floor of David Jones' for the next three weeks.

**This clipping, believed to be from the "Wollongong Mercury" around 1968, shows the original fridge-sized OSCAR noughts and crosses "machine". No, those aren't LEDs in the display – they weren't even a glint in a mad scientist's eye back then . . .**

derstood well, this was very exciting. Lots of my older friends still remind me about "OSCAR".

We initially did not know even how to start to build such a machine. We eventually worked out that the machine had to go through a logical series of steps, in sequence. We never called it a program but of course, it *was* a program.

I have never forgotten the sequence, so now that PICs have become available, I set out to put the exact same program from 1968 OSCAR into a 2007 PIC16F84A.

## The new Oscar

The new Oscar is a tiny fraction of the size of the original. Instead of requiring a lot of power to operate, it will run for months on a couple of batteries. It has nine green buttons in a 3 x 3 array and nine bicolour LEDs also in a 3 x 3 array.

When you press a button, to take your first turn, the corresponding LED illuminates green. Oscar now "thinks" for a second or two and then has his move, illuminating his position red.

It is now your chance to have your second move – and I think you know the rest.

If OSCAR wins, which is pretty common, the winning row of three red LEDs flashes, calling attention to the player's demise(!) and the game is halted. You cannot continue when you have been defeated.

There are two more buttons. The white button is to reset OSCAR for a new game and the red button is to allow OSCAR to have the first move in the game. It is polite and fair to give OSCAR the first turn at least sometimes. OSCAR is very clever here, as the square he chooses for his first move is truly random.

Generating truly random numbers is difficult for a PC and very difficult for a PIC but OSCAR employs a trick here.

At the end of a game, following a reset, OSCAR is not just sitting there doing nothing, not at all. He is counting rapidly one through to nine, and again one through to nine at high speed, until you press a key to start the game, at which time he stops counting. The number that he stops on will be the square he chooses if you give him first turn. I thought that was clever, as the number is truly random.

## How it works

If you glance at the circuit you will see that it is quite simple and does not use any active components apart from the PIC.

The circuit is powered from four AA batteries that sit in a plastic battery box available from Jaycar. The maximum voltage for the PIC is 6V, so don't get tempted to install a 9V battery.

This PIC can have various oscillators but in this case, we are using a resistor/capacitor circuit on pin 16 of the chip. With the values chosen the circuit oscillates at around 700kHz. The RC oscillator is a little cheaper and somewhat slower than a crystal, making delay loops easier.

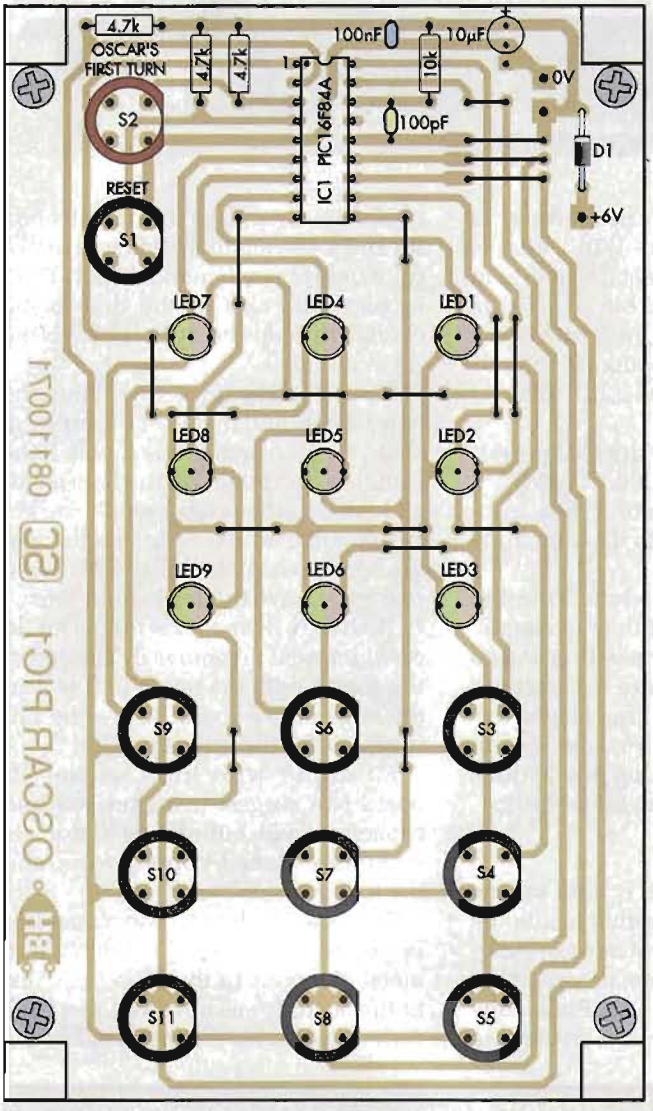
You can see the 700kHz triangular waveform on pin 16 with a 'scope and high impedance probe. The PIC divides this by four to become the system clock and you can see the resulting 180kHz square wave on pin 15.

Because we are connecting so many devices to the PIC we need to do some multiplexing. The PIC has only 13 input/output connections available, but we have nine position buttons, nine red LEDs, nine green LEDs and a couple more buttons.

If you have a look at the circuit you will see that for each of the nine locations, the common cathode of the green/red LED, and one side of the push button are all connected together, so we have a common connection for button, red LED, and green LED, and of course there are nine separate common points.

The PIC holds these lines high at 5V and then, one at a time, drops the line to 0V for around one millisecond, then puts it back up to 5V and drops the next one to zero for one millisecond and so on.

So the PIC is scanning from one to nine, relentlessly, regardless of the



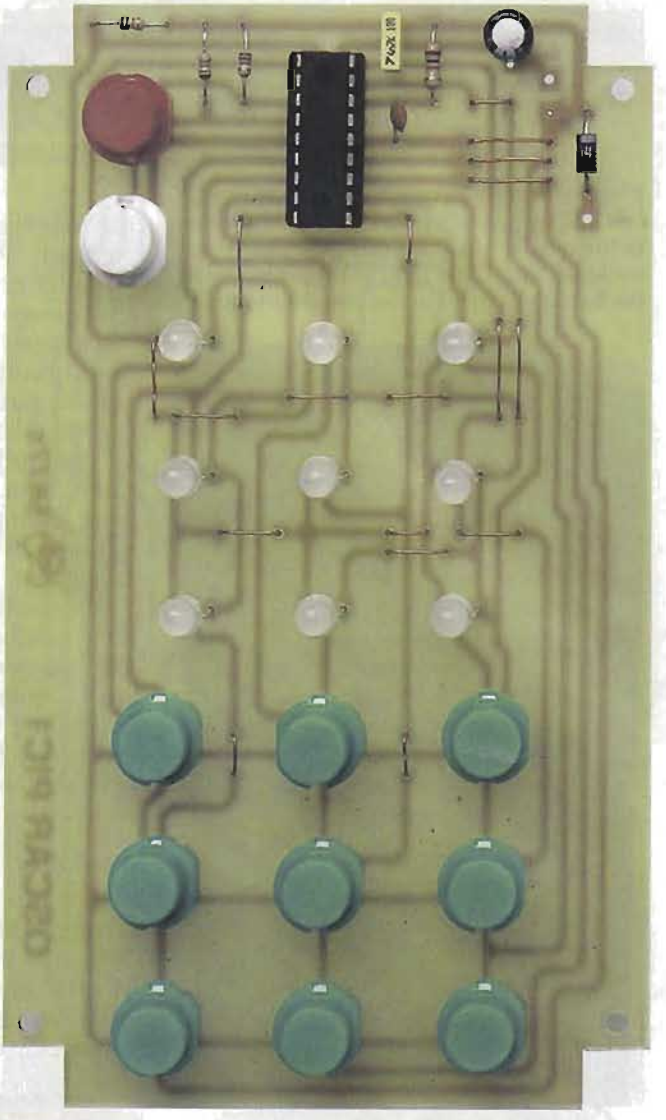



**Fig2: the component overlay (viewed from the component side with the tracks as if in X-ray), with the same-size photo alongside. In the prototype ordinary copper wire was used for the links but we suggest tinned copper wire to prevent oxidation.**

state of the game.

Let's now look at the PIC pins 1 and 18. These pins are configured as outputs from the PIC and are normally held low by the PIC, pin 1 connects to all the green LED anodes and pin 18 connects to all the red LED anodes.

If, during the scanning, the PIC needs to illuminate, let's say, green LED number six, it waits till the scanning reaches position number six and then, just for one millisecond, while the cathode is held low, it raises the anode via pin 1 of the PIC to 5V. Only that LED will light because it is the only one with power on one end and 0V on the other end.

In this way the PIC lights the LEDs one at a time at high speed, so you are unaware that they are actually flashing rapidly.

It will never light both green and red for the one location, as that situation never occurs.

The common sides of the pushbuttons are all connected to pin 2 of the PIC configured as an input and held high by R4. If you press a button, this pin will be pulled low when the scanning reaches that position.

Now that you understand the wiring, during an actual game, as the PIC is scanning each position, for the one millisecond when the common point is pulled low, if the LED should be green, pin 1 will be made to go high, if the LED should be red, pin 18 will be made to go high, if the position is not occupied, no red, no green, then, and only then, the PIC will look at pin 2 to see if the button has been pressed.

This means, if the player presses the button for a position already occupied, it is ignored.

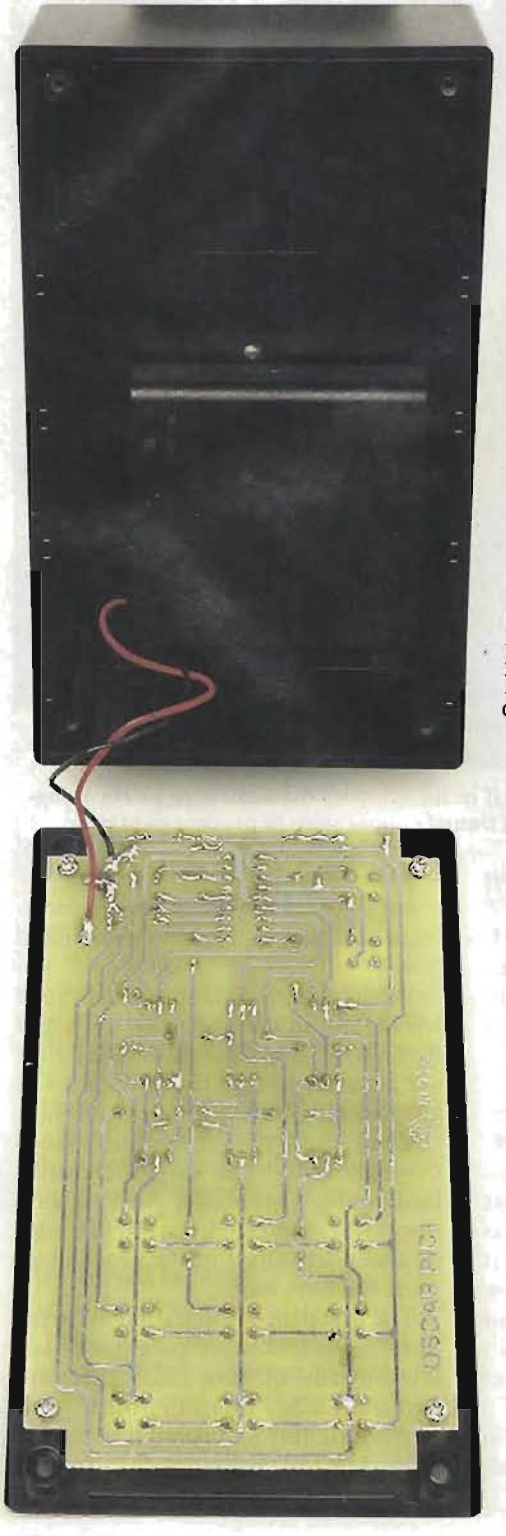
## Software

Let's ignore the housekeeping software and just look at the game logic itself.

When you press a button, the green LED is illuminated immediately, and then there is a deliberate delay of 1 – 2 seconds so that Oscar appears to be "thinking".

Then the PIC very rapidly goes through four separate procedures, looking for a response. As soon as a response is indicated, the PIC executes it, and quits any further procedures until the next move.

The first procedure, called "Win for Sure" is to test every position to see if in any row of three LEDs, there are two red LEDs lit and the third position blank. If it finds one, it of course puts a red LED there, stops the game, declares a win etc.



**These two shots give a good idea of how OSCAR fits together. The PC board screws to the box lid via standoffs with the switches and LEDs poking through, while the battery is fixed to the bottom of the box.**

The second procedure is called "Prevent Win" and is similar to the first. Its job is to test every row to see if there are two green LEDs in a row and a third position blank. If it finds one it puts a red LED there to prevent defeat.

The third procedure is the most difficult. It is called "Tactics". It goes through quite a few algorithms and tries to do something intelligent.

The fourth procedure, if the first three produce nothing, is simple: just find an empty position and go there. There is more software for responding when the player lets Oscar have first turn and also to highlight the winning row of three red LEDs by making them flash.

## Assembly

The whole circuit is built on one PC board which mounts inside the lid of a jiffy box. The most difficult part of the construction process is the precise drilling of the lid. Photocopy or cut out the front panel art and use it as a template. Tape it to the jiffy box lid and u se a small drill first to drill a pilot hole for each marked spot. Then increase the size of the drill being careful to keep the drill at 90° to the lid at all times.

Check that the LEDs will fit into the holes easily and that the buttons have about 1mm clearance all around. If the switches get caught on the hole edges and jam on, the project won't work!

Assemble all the components onto the board except the LEDs. This is important – leave the LEDs until later.

It's best to use a socket for the PIC in case you need to remove it. The end of the socket with the notch in it is near the edge of the board. Leave the PIC itself out for the moment.

Fit all 18 wire links on the PC board (we suggest using resistor and capacitor lead cut-offs as these are invariably tinned copper wire) and the four resistors.

The small electrolytic capacitor is polarised. Install the four 10mm metal standoffs to the PC board. Test fit the board to see how well you have drilled the holes for the buttons; file

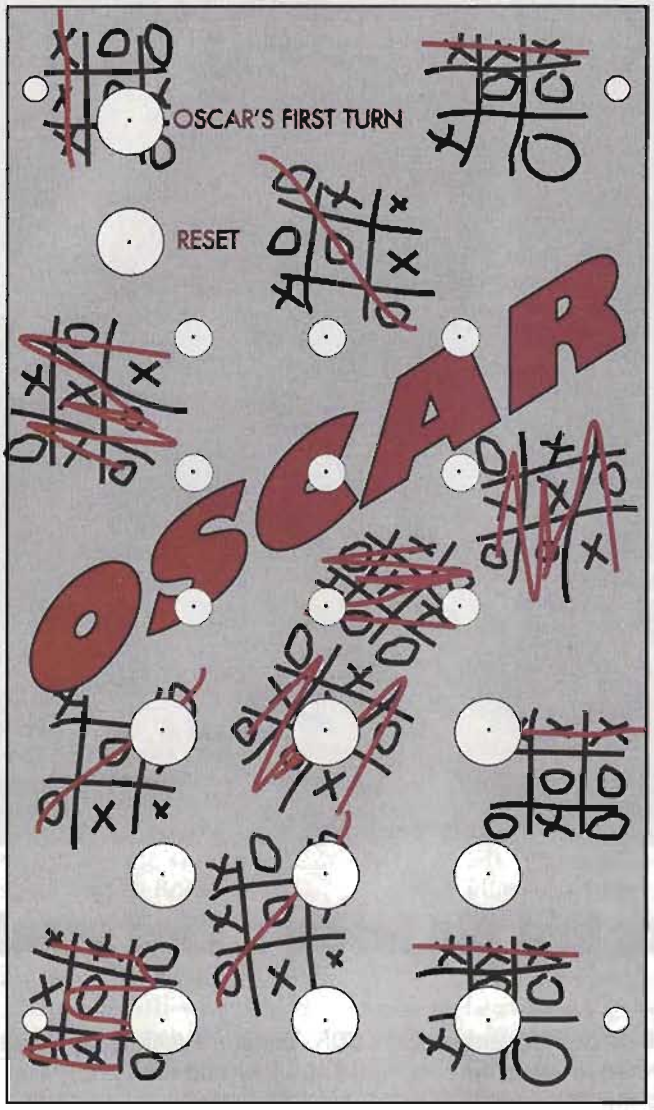
### Parts list – OSCAR Noughts and Crosses Game

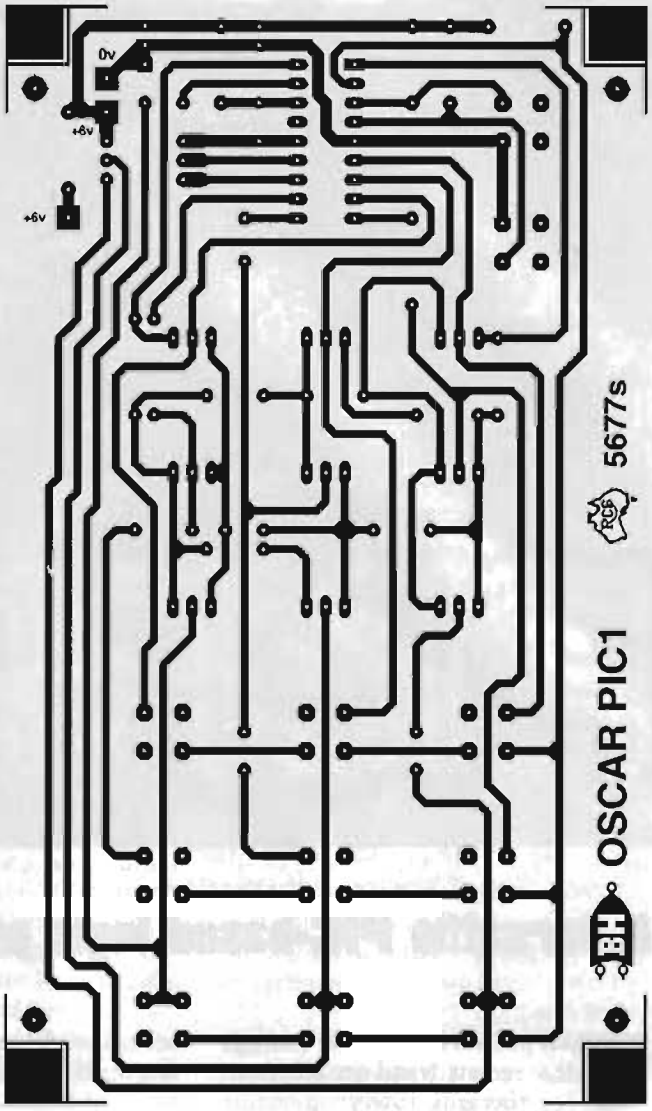
1 OSCAR PIC1 PC board, 145 x 86mm code 08110071
1 158 x 95 x 53 mm (UB1) jiffy box (Jaycar HB6011)
1 4xAA battery holder with switch (Jaycar PH-9282
4 AA batteries
9 green PC pushbuttons (Jaycar SP- 0724)
1 red PC pushbutton (Jaycar SP- 0720)
1 white PC pushbutton (Jaycar SP- 0723)
1 18-pin IC socket
4 10mm long, tapped 3mm metal stand-offs Jaycar HP-0900
8 3mm screws 3M 6mm long

**Semiconductors**
1 PIC16F84A preprogrammed with OSCAR.HEX (IC1)
9 red/green 3-terminal LEDs (WES components LED5GRY)
1 1N4004 silicon diode (D1)

**Capacitors**
1 10µF 16V electrolytic capacitor.
1 100nF miniature polyester capacitor (Code 104, 0.1 or 100n)
1 100pf ceramic capacitor (Code 101 or 100p)

**Resistors** (0.25W, 5%)
1 10kΩ (Code brown black orange gold)
3 4.7kΩ (Code yellow purple red gold)




**Figs 3 and 4: full-size artwork for the front panel (which can also be used as a drilling tempate) and the PC board, viewed from the copper side. Note the four cutouts required in the corners of the PC board so it can fit past the pillars in the box.**

or ream the holes a little if necessary. When you are happy with the fit of the buttons in the holes, fit all nine LEDs into the holes in the board, taking great with the polarity (flat side is on the anode 1 [red] leg) but don't solder them just yet.

Now mount the board on the lid using the standoffs and fit the screws to both ends, so that the board is in its correct position. Push the LEDs one at a time hard into the corresponding hole in the lid. Make sure that it is fully pressed into the hole in the lid and now solder it. Repeat till all LEDs are soldered in.

If you have done this well, all the LEDs will be protruding through the lid the same amount, around 3mm. When you are fully satisfied with the mounting of the LEDs, snip off the excess lead.

The battery box can be attached to the bottom of the jiffy box with double sided tape.

Fit the PIC to its socket, install the batteries, switch on and give it a go.

## Faultfinding

If you have any trouble with any of the functions you can check out the board as follows.

First power off and remove the PIC, then make a short jumper out of a single strand of telephone wire. Put one end in pin 14 of the socket and the other end in pin 18.

Put one end a 220Ω resistor in pin 5 and the other into pin 6. The first LED should light red. Swap the resistor end from pin 6 to pin 7 and the second LED should light red. Keep going into pins 8,9,10,11,12,13 and 17 and each LED should light red in turn.

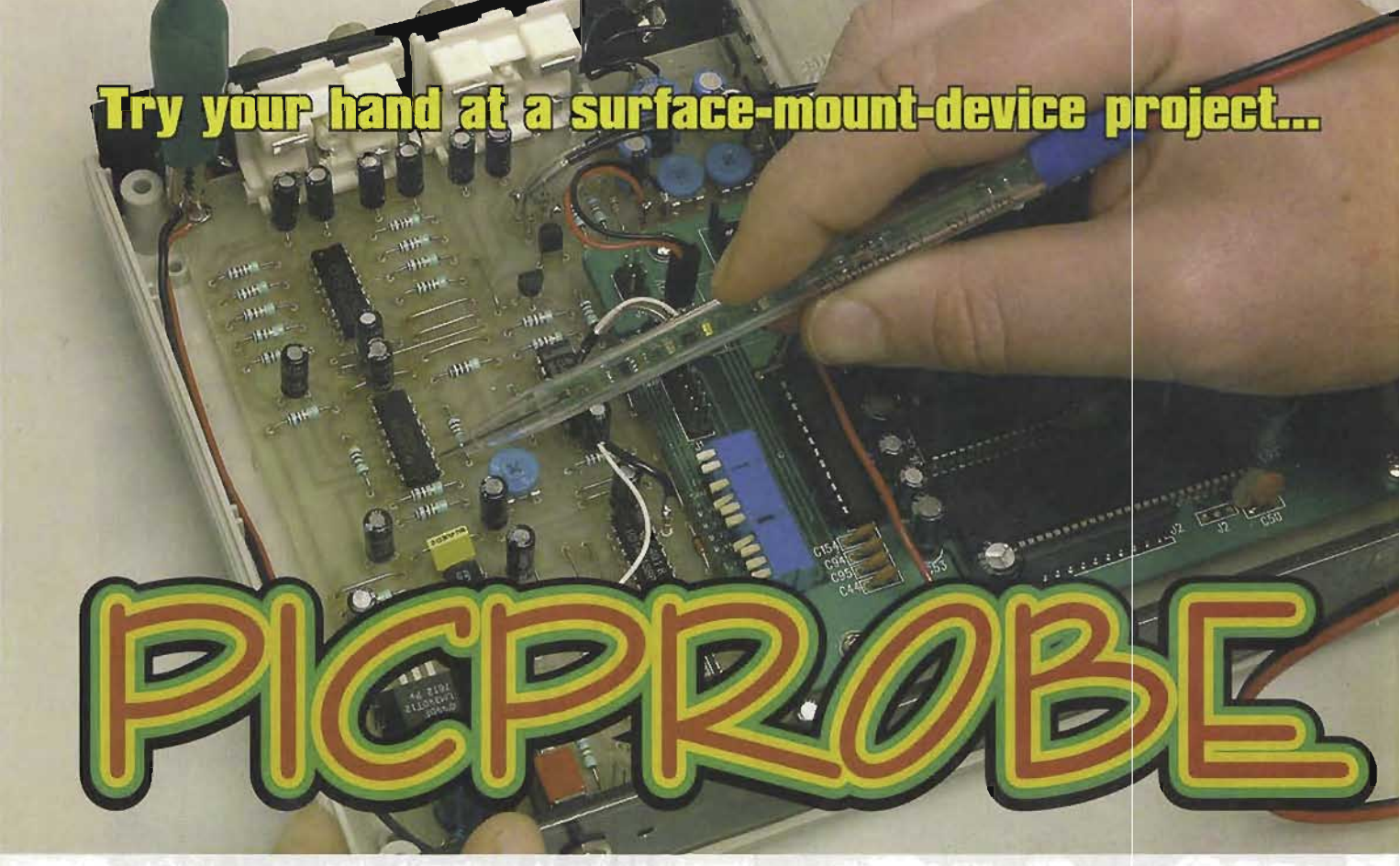
To check the green LEDs, change the jumper linking pins 14 and 8 to pins 14 and 1. Repeat as above with the 220Ω resistor and again, each LED should light green in turn.

If you have a LED in backward it will light green when it should have lit red and vice versa.

If these checks are OK then it is highly likely that you have a faulty PIC or it has not been programmed or programmed incorrectly.

## The software

We imagine that the PIC16F84A will be available preprogrammed but if you can't get it, or wish to do it yourself, OSCAR.HEX can be downloaded from www.siliconchip.com.au free of charge. The PC board pattern and front panel artwork will also be available from the same source. SC



Try your hand at a surface-mount-device project...

# PICPROBE

## A versatile PIC-based logic probe that fits inside a Biro case!

**This project came about** through the recent trend in electronics towards lower operating voltages. If you look around at the latest chips being offered from semiconductor manufactures you will see that most are designed to operate on 3.3V or lower.

Having done a few recent designs with 3.3V circuits, I discovered that my old favourite test tool, the Logic Probe, wouldn't operate below 5V.

I looked around my usual electronic suppliers but couldn't find anything that would work on anything less than 5V. So I thought I'd build design and one.

The first requirement I had was to make it work over as wide an operating voltage as I could so that it could be used on the old legacy 5V systems and down to some of the latest processors at 2.8V, the second was low cost.

I took a look inside the existing probes I had, only to discover them to be full of analog components, some of which were now obsolete.

The quickest and easiest approach seemed to be to build something out of a small microcomputer, so I went on the hunt for anything that was small, cheap and worked on a wide supply voltage.

Where I ended up was at the Microchip website looking at our old friend, the PIC.

One of their latest additions to the ever-expanding family is the 10F20x series which are available in DIP-8, SO-8, or SOT-23-6 packages. The SOT-23-6 was my choice as these are tiny and easy to put inside some type of pen as a housing.

My next mission was to find a housing for the design. Having built a Logic Pulser from a magazine article many years ago into a white board marker pen, I decided to check out the local stationery shop for ideas. If I could find, say, a pen moulded in clear plastic I wouldn't need to drill holes to view the LEDS, therefore making it easier to build and it would look pretty cool as well!

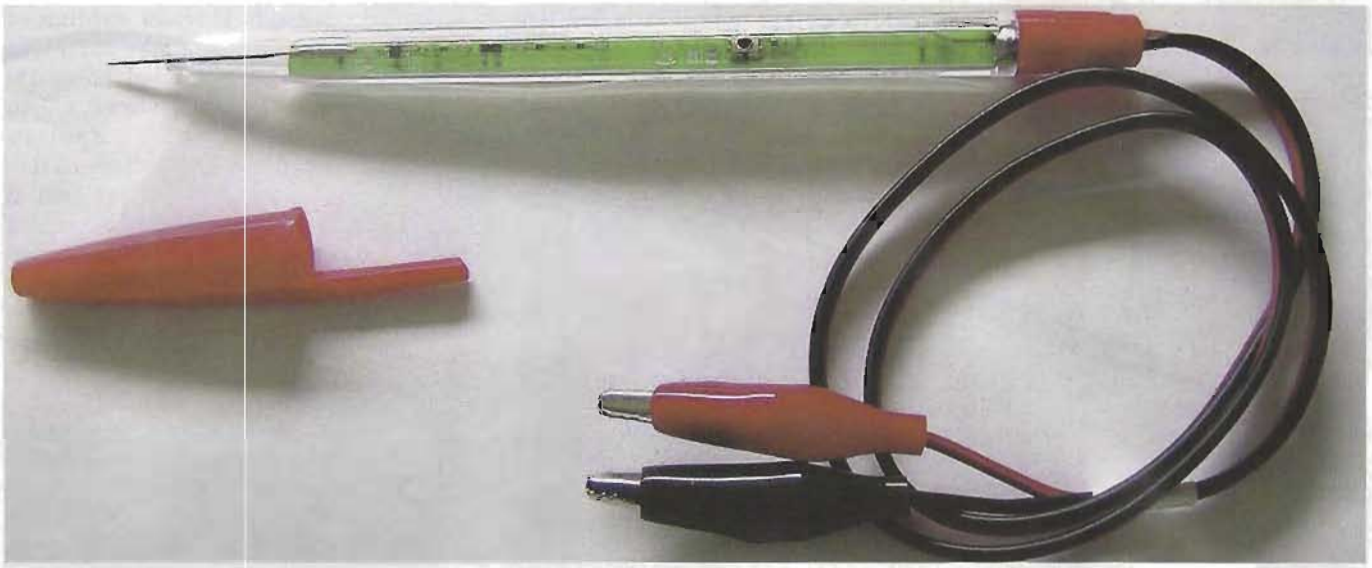
**from an original by Ross Purdy**

I found a 10-pack of ballpoint pens that looked about right and cost only $2 making for a very cheap case - including an end cap to protect the pointy bit. The pens were a bit on the small size, allowing for a PC board only about 5mm wide and 100mm long but it was the height that I was more concerned with.

I cut out a dummy piece of circuit board and glued a few bits on and found that the micro and LEDS would fit easily down the barrel of the pen.

With the micro and housing sorted out I concentrated on the functionality required.

First and foremost was a good sharp tip that you can use to probe tiny pitch devices that were/are becoming increasingly common. A sewing needle seemed to fit the bill quite nicely here. I also wanted to have a pulse stretching or latching function to view and change very quick pulse transitions so a switch would be required to change



**This photo shows the first prototype without the extra components added for higher voltage operation or input protection. Don't forget to keep the pen cap – it can save some nasty stabs! Also note the S1 access hole in the pen body.**

modes and clear the pulse latch when required.

## We changed the design!

You will see from the schematic (Fig.1) that there isn't much to the design. But this has some differences to the circuit and project originally submitted by Ross Purdy.

One of the main changes involved re-designing the PC board itself so that it was single-sided.

There are still a lot of hobbyists who make their own PC boards but only a small percentage of those have the equipment to make a double-sided board. And commercial double-sided boards are quite a bit more expenisve than single-sided – we're happy to swap the inconvenience of a few links for the convenience of a second side to the PC board, if on no other grounds than cost!

Note that the links go on the "normal" top side of the board (ie, the non-copper side) and some of them cross, so they should be insulated copper wire.

We also added provision for a 5V regulator on the PC board. While we agree with Ross's comments about operating from low voltage (normally taking its supply from the device under test), we also knew there would be a lot of hobbyists who might want to use the probe for testing devices with higher voltages.

So we made it an each-way bet by including the pads and tracks for a 5V SMD regulator (78L05, REG1). Due to the miniscule power drawn by the circuit, the regulator should be quite happy working up to its maximum input voltage of 30V.

If you only want low voltage operation, the regulator can be left out and a link added to connect the DC in and DC out pads (where the regulator would be). The regulator input and output filter capacitor can remain – they won't do any harm and may even do a bit of good in decoupling a supply.

We've specified 100nF capacitors because we have found these are the easiest to get in SMD and in small quantities. But there would be some benefit if one of the two "downstream" capacitors (ie, between the regulator output and ground) could be larger – in fact, as large as you can get in SMD.

The final change was in the input circuitry. The PIC only has six pins, two of which are the power supply. GP3, the probe input, can withstand a maximum of 13.5V. In the vast majority of circumstances this would be more than adequate but once again, we've "gilded the lily" somewhat.

We placed a pair of diodes across the input (one each to the positive supply and ground) along with a series resistor. This protects the input from accidental higher voltages and for the price is a worthwhile addition.

This is very handy in case you touch something at a higher potential than the power supply. If you don't need

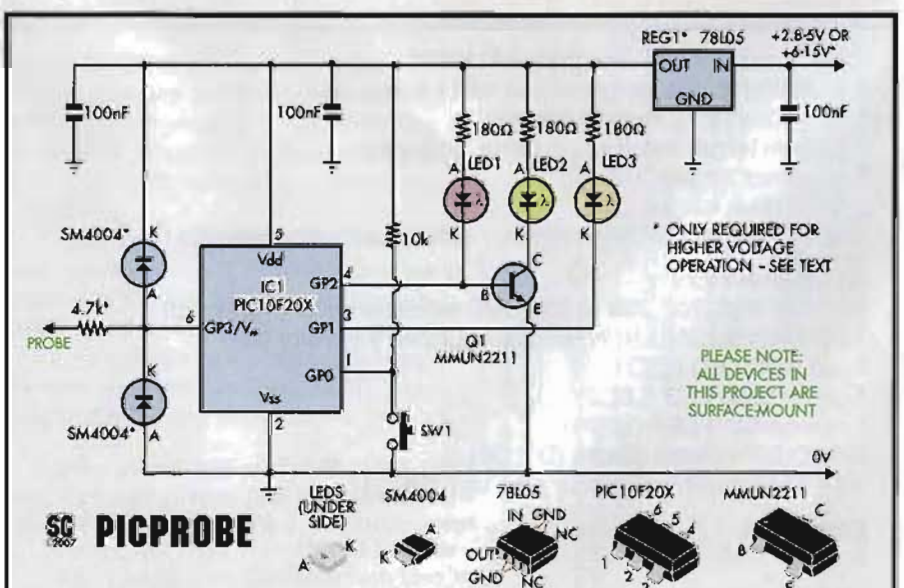
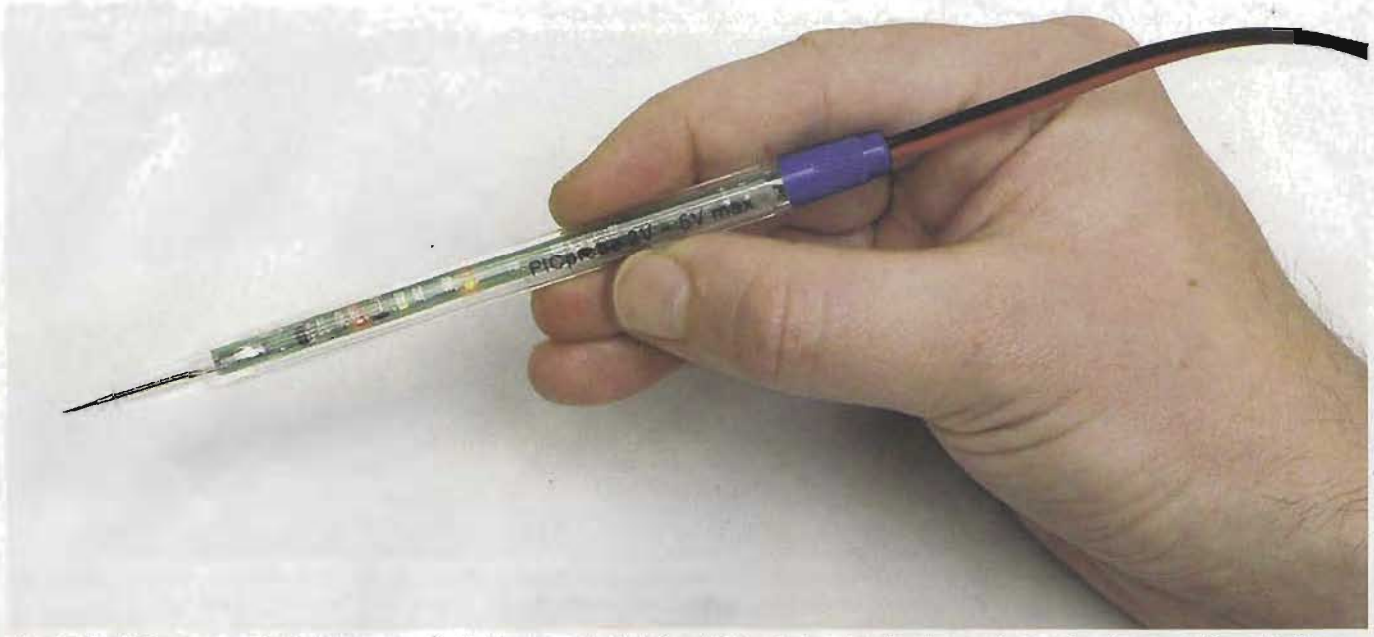



**Fig.1: the circuit can be built in two versions – that shown here, suitable for general purpose work or without REG1, suitable for lower voltage work.**



**The SMD LEDs are really bright, especially in normal lighting. This photo clearly shows them glowing even though they have been "swamped" by the very bright photo flash we used for the photo.**

this protection, the diodes can simply be omitted. The resistor could be retained, or replaced by a wire link if you wish. It won't matter either way.

## OK, back to Ross's design!

Surface-mount LEDs, so tiny that they are almost impossible to find if you drop them on a carpeted floor (trust us!), are directly driven from the PIC's GP2 (red LED) and GP1 (orange LED) outputs. The green LED is driven by the inverse of GP2, using transistor Q1.

Even though Q1 is shown on the circuit as a standard NPN type, it's a bit more complicated than that. It is actually a "Resistor Equipped Transistor" which has two internal resistors: a series resistor to the base and a pull-down resistor to the emitter. These 'RET' devices are great for using as digital invertors.

GP0 is normally held high by a 10kΩ resistor connected to the positive supply. It's also connected to a pushbutton switch w hich grounds the input when pressed.

## Parts List – PICPROBE

1 PC board, 5 x 106 mm, code 04110071
1 clear plastic ballpoint pen case with top and cap
1 ~35-40mm long darning needle
1 500mm length thin figure-8 cable, polarized
1 small red alligator clip
1 small black alligator clip
1 ultraminiature (SMD) momentary action pushbutton switch

**Semiconductors**
1 PIC10F200, 202, 204 or 206 SMD microcontroller (Microchip)
1 MMUN2211 SMD NPN resistor-equipped transistor (Q1)
1 red SMD LED (LED1)
1 green SMD LED (LED2)
1 orange SMD LED (LED3)
2 SMD GP sSilicon diodes (D1, D2)
1 5V SMD positive regulator (see text) (REG1)

**Capacitors**
3 100nF SMD

**Resistors** (all 603SMD)
1 10kΩ 1 4.7kΩ 3 180Ω

## Which PIC?

The circuit shows a "PIC10F20X" but you won't find one of these in any catalog. What you will find is a PIC10F200, 202, 204 or 206 – and any of these will work in the design as the program was written for the 200, which has 256 bytes of program, 16 bytes of RAM, and one 8-bit timer.

The "X" in the type number simply replaces the last digit.

## Operation

The probe has three LEDs and a push button. The Red LED is turned on for a logic 1 at the probe tip while the Green LED turns on for a logic 0.

The Orange LED works in one of two modes, pulse stretch or latched. In pulse stretch mode the orange LED will pulse for 50mS every time there is a change on the probe input. This makes very small pulses at the probe tip viewable. If the orange LED stays on permanently in this mode then the probe tip is changing at a rate greater than 50ms. In latched mode the orange LED will turn on and stay on with any change on the probe tip. This is handy for detecting very infrequent changes. The latch is cleared and the LED turned off when the button is pressed.

The push button has three functions: (1) changing orange LED mode, (2) clearing the latch and (3) enabling a pull-up resistor on the probe tip.

To change modes you press and hold the button for two seconds. After two seconds the orange LED with blink

to indicate mode is about to change. When the button is released the mode is toggled. In latch mode a single press of the button will immediately reset the latch.

If the button is pressed when power is first applied a pull-up resistor on the probe tip is enabled. Normally the pull-up is disabled, which makes the input impedance very high. In this configuration the LEDS will flash randomly until the probe is connected to the target test point.

This is very useful for tracking down floating circuits on the target under test. If this is not an issue then enable the pull-up and the tip will go to a 'soft' logic 1. The only way to reset the pull-up is to re-power the probe.

## The software

Internally, you don't get much room to play with in this tiny PIC. Because the device is so small and the task relatively simple, it was written in PIC assembler using the PIC IDE 7.5 tool kit, which is available free from www.microchip.com. The IDE gives you an editor and assembler and is quite easy to learn.

As this micro has no interrupts and very little resources it doesn't take long to master but as I found out, there are a few traps for young players. The first thing to master is the internal oscillator and its calibration, if required.

When the device is manufactured it has a MOVLW instruction loaded into the last byte of the memory. On power reset the micro starts at the last address and executes the MOVLW instruction. This loads a calibration value into the W register and is factory set. The program counter then rolls around to 0 and starts executing the users code.

The problem comes when you erase the device and lose the MOVLW instruction. If you want a 4MHz calibrated oscillator you need to read the last byte and write it down then manually put it back in. All this seemed unnecessary for my application as I wanted it to run as fast as possible. As the first instruction I loaded W with 0x7E which makes the oscillator run at its fastest speed.

The next item to master is the internal timer. This is a bit tricky as the micro has no interrupts to trigger asynchronous events. The timer is free-running and you can only read the timer register and compare it with a constant. Any write to the timer will clear it and start timing again so you can't use any read-modify-write instruction.

This was a trap I fell into. I have run the timer at 50ms per overflow (counts from 0x3d to 0 in 50ms then is reloaded with 0x3d). If you check and branch when the timer is zero you can have a routine which is executed at a regular period for timing tasks.

The program begins by setting the oscillator configuration, port pin configuration (inputs or outputs), starting the timer, and resetting the LEDs.

As the processor has no interrupts the only way to monitor the probe tip is to poll it. This is done in the main loop and the smaller the main loop (or the quicker it executes) the smaller the pulse transition that can be detected. This is one limitation of the design but in practice it doesn't appear to be a problem.

The main loop moves the state of the probe input to the red/green output, checks the status of the mode change flag and looks for the timer to reach zero.

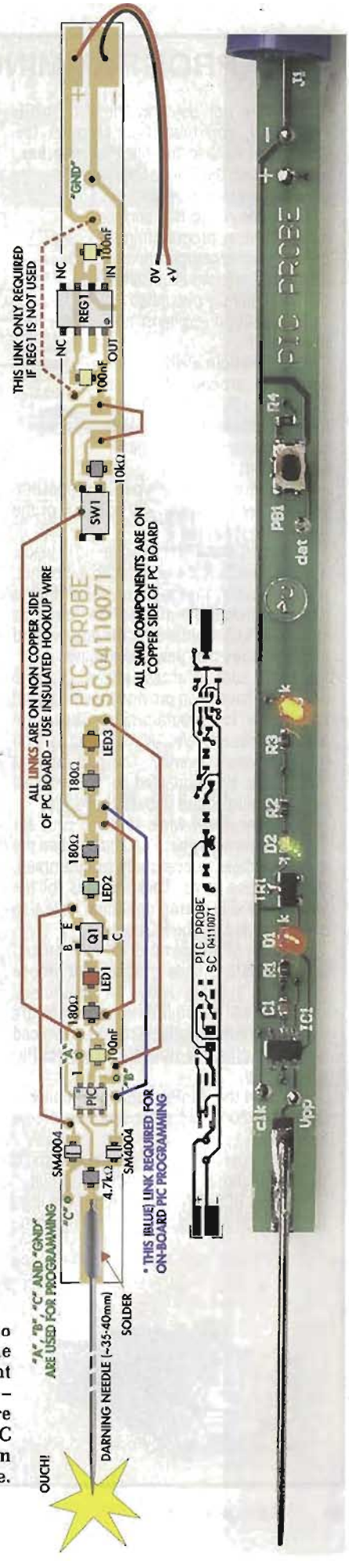
Every 50ms the time function is called. The job of the time function is to check that the button has been held down for two seconds and to update the orange LED in either pulse or latch modes.

First we will look at the button down timer. To do this we have a variable called CNT0 which is preloaded with 40. Every time the time function is called we decrement CNT0 if the button is pressed. If it is not pressed we reset CNT0 back to 40. The only way CNT0 can make it to 0 is if we have 40 consecutive calls to time with the button pressed (40*0.05=2 seconds). When CNT0 reaches 0 we set a flag (BDOWN) to signal to the main loop that the mode change function needs executing.

The orange LED is handled with different pieces of code depending on the mode set, the flag LATCH determines the mode.

Every time the red/green LED changes state we set a flag (CHANGE). This flag is read by the time routine.

**Get the point? You will if this sticks into you. Be careful! Note that this photo of the finished project and Fig.2, the component overlay, are NOT reproduced life size – you'd hardly see them. In fact, they're shown almost double size. Fig.3, the PC board pattern between the two, *is* shown life size.**



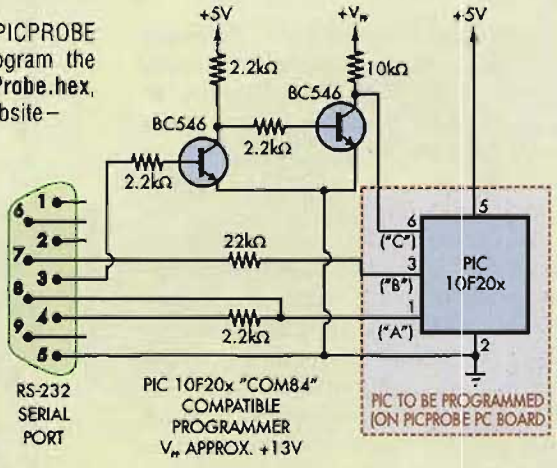
## PROGRAMMING THE PIC CHIP

If you're not building the PICPROBE from a kit, you must first program the 10F20x micro with the file **PicProbe.hex**, available from the Silicon Chip website – www.siliconchip.com.au.

Since the micro is a surface mount device, programming it presents added complications. It must be done in circuit but before the board is fully populated.

This section explains how to do this.

You need both a VPP voltage source of around +13V and a normal +5V supply. If you have decided to use the 78L05 regulator, you can derive the 5V supply from that.




If you have chosen to bypass the regulator, you will need to apply +5V to pin 5 of the micro with 0V at pin 2.

The micro must first be soldered in place, making sure that the orientation is correct. If you are using the regulator, solder that in too. Also install the marked link (blue) as shown in Fig.3. Solder both the positive and negative wires that power the board.

Special pads to access pins 1, 3 and 6 of the PIC have been provided on the board specifically for programming. These are labelled, respectively, "A", "B" and "C" on the component overlay. The pad labelled "GND" can be connected to the external programming circuit shown above.

You may solder wires to these pads for the programming phase and later, when the micro has been successfully programmed, remove these wires. Back-up pads for the links required in normal operation have also been provided on the PC board.

The type of programmer we recommend is the "COM84" style programmer whose schematic appears above. A computer's serial port will be required and the software to use is WinPic, available free to download from www.hamradioindia.org/circuits/winpic.php.

We used the WinPic version compiled 9 December 2005, but other versions should be similar.

After soldering the wires to the A, B and C pads, you should breadboard this circuit.

The two BC546 NPN transistors are used to switch on and off the higher programming voltage, which for normal pro-gramming should be between 12.5V and 13.5V at pin 6. Adjust your input VPP voltage level to within this range. There will be a small voltage drop across the 10kΩ resistor in series with VPP and pin 6/collector of BC546.

When the Tx line (pin 3) of the serial port is low, the voltage at pin 6 of the PIC10F20x should be around 0V. When it is high, it should be between 12.5V and 13.5V. The WinPIC software will automatically switch this voltage on or off as required.

To access the serial port, we used a serial cable with an IDC 10 pin header attached, as in the photograph below.

Once you are satisfied that the circuit is working correctly, you may connect the serial cable to your computer's COM1 port.

Now you should run the WinPic programmer. You must first select the "COM84" programmer for the serial port in the "Interface" tab. While you are there, check that the interface is working correctly by clicking on the "Initialize!" button. If everything is working ok you should get the message "Interface tested ok". If not, double check your wiring.

Now go to Device>Select... and select the PIC10F20x as your device.

You now should be able to erase, program and read the micro. To load the firmware, go to File>Load and select the PicProbe.hex file. Then choose Device>Program to program the micro.

If this worked, go to Verify to check that the firmware has been programmed correctly.

In pulse-stretch mode the orange LED is turned on when CHANGE is set and then CHANGE is cleared. If CHANGE is not set the orange LED is turned off. This means that the minimum time that the orange LED is on will be 50ms which is more than enough for your eye to see.

Latch mode is similar, in that when CHANGE is set the orange LED is turned on but is not cleared until the button is pressed, this is detected using the BPRESS flag.

Mode changing uses a separate function labelled cngmode. When this function is called it will blink the orange LED using simple delay loops until the button is released. When the button is released the LATCH flag is inverted and the routine exits back to the main loop.

### Construction

If this is your first SMD (surface-mount device) project, you will find there is a rather radical difference between handling, fitting and soldering these devices and conventional components.

For a detailed explanation, we refer readers to pages 42 and 43 of the October 2006 issue.

The other big difference in this project is the size (or lack thereof!) of the PC board. Like the SMDs themselves, it is tiny: just 5 x 106mm.

The first prototype PC board we received looked perfect but when we checked it out, it was too big to fit inside the pen case (it had been trimmed to the *outside* of the corner marks, a difference of perhaps 0.3mm each side). So we had to file it down to the inside of the corner marks

If by chance you have to do the same, it's easiest (and you get a straighter edge) to hold the file flat in the vyce and run the edge of the PC board up and down the file, rather than try to hold the PC board in the vyce and file off the excess in the usual way.

The PC board should be a relatively snug fit inside the pen case. But don't push it all the way in to check – you may not be able to get it back out again.

We are assuming you're building the PICPROBE from a kit – ie, the micro is already programmed.

Normally we solder components, then the "hardware" to a PC board. Here the components are the smallest items (particularly the LEDs) so its

easier to solder on the probe tip, switch and external connection wires first, then move onto the SMDs.

As we mentioned earlier, the tip is a sewing needle. These are often nickel-plated, which makes soldering a bit difficult. Test first – if it is difficult (or impossible) to get solder to take, you may need to file off a small section of the nickel plating.

The size of the "probe" is up to you – and the type of work you'll be doing. We'd be inclined to use a small darning needle, as these tend to have less of a point (so you won't get stabbed!) but are still fine enough for the vast majority of work.

The needle we used was about 35mm long and so far, still hasn't been missed from the sewing box (;-).

Don't forget that the power wires (polarised figure-8 cable) need to pass through the pen top cap so it is wise to do this now, rather than later. You'll need to drill a hole in the end of the cap to accommodate the wires.

You need to decide if you want your logic probe to be suitable for low voltage work (as in the original design) or for general purpose, higher voltage work.

If it is for low voltage (ie, 5V or less) work, leave out the voltage regulator and place a link between its input and output positions. Normally we'd say to use a resistor lead offcut. Not this time, though: there aren't any!

The last component to be fitted should be the PIC chip, if only because that allows you to check the LED operation before putting the PIC chip in.

To do this, connect power and in turn short the cathodes of the each of the LEDs to ground (0V). Each should light in turn (you won't do any harm to Q1 doing this).

As you do this, also check that the colours are correct: red towards the probe, orange in the middle and green towards the switch.

If your LEDs light, it's a pretty good bet that you haven't made any mistakes or shorted out any SMD pins.

Remove power, wait a few minutes and then fit the PIC chip to the board.

Apply power again – the LEDs should be flashing in an apparent random fashion but only one should be lit when you touch the probe tip to the positive supply and then 0V (which of course equates to a logic high and logic low).

Assembly is now complete – all you have to do is drill a 2mm hole in the pen case as shown in the photo to access S1, then slide the completed PC board into the case until the switch is right under the hole.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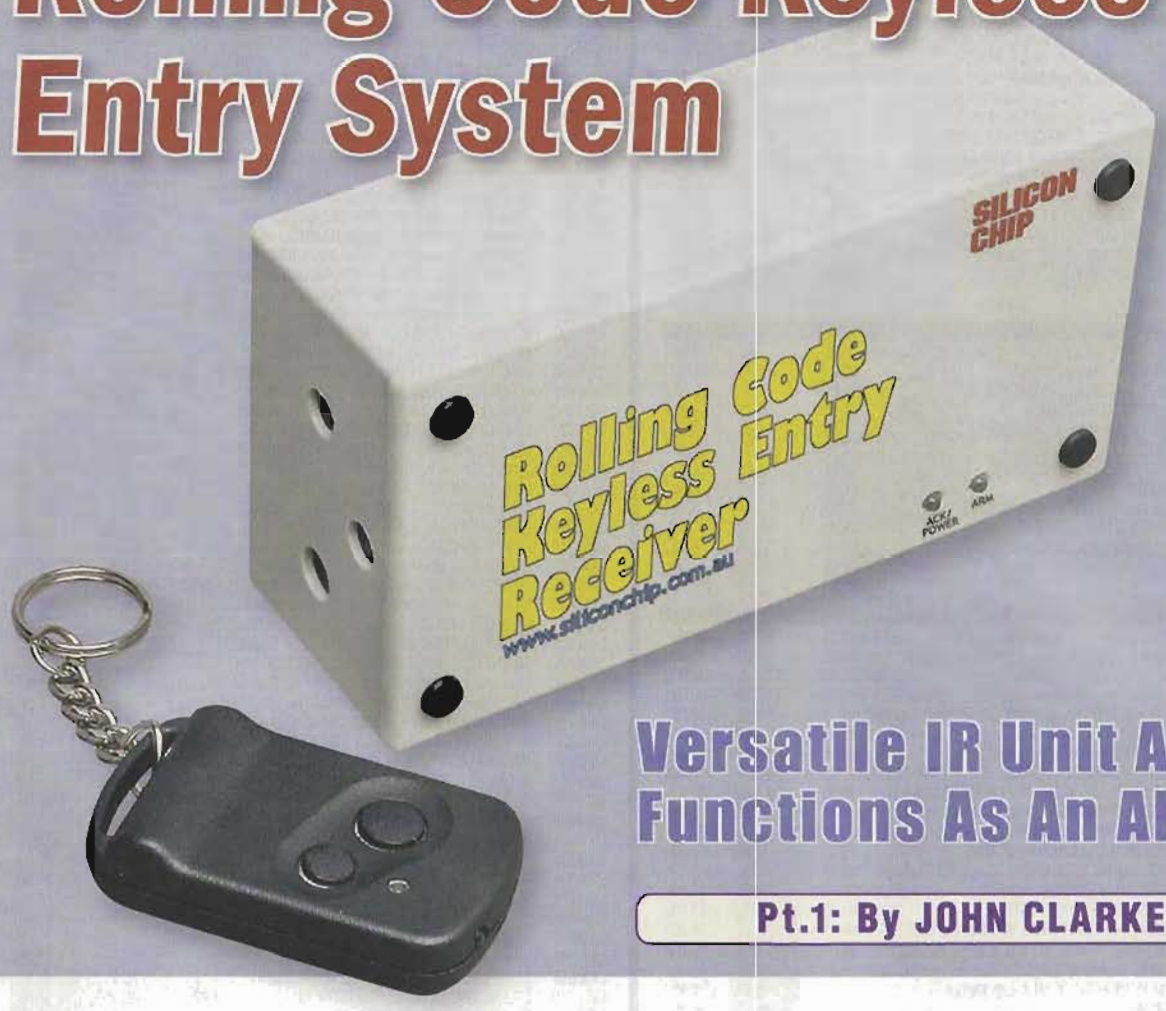
## Where do you get it?

As we went to press, we were informed that both Jaycar Electronics and Altronics will be putting a kit of parts together for the PICPROBE.

Jaycar's kit includes the PC board and all components, including the pre-programmed micro but not the pen or the needle. It will retail for $14.95 (Cat KC5457). (www.jaycar.com.au)

Altronics kit is similar with a pre-programmmed micro and no pen nor needle. It also sells for $14.95 (Cat K-2587). (www.altronics com.au)

# Rolling Code Keyless Entry System




## Versatile IR Unit Also Functions As An Alarm

Pt.1: By JOHN CLARKE

**Ideal for keyless entry for doors in cars, homes & industry, this Keyless Entry System features a rolling code to ensure high security. It also has two door-strike outputs, an alarm system & provision to use up to 16 separate keyfob transmitters with the same receiver.**

LOTS OF DIFFERENT electronic systems have now been developed for keyless entry. These include systems that require a coded electronic key, such as RF and infrared transmitters, RFIDs (Radio Frequency Identification Devices), keypads and swipe cards. There are also units that do not require a coded electronic key and these include fingerprint, face and iris recognition.

Regardless of format, electronic keys usually comprise a small keyfob-style transmitter and a receiver that goes with the door lock mechanism. The transmitter sends a string of data that is unique to each individual lock and this data must match the data stored in the receiver before the lock will be released. The concept is roughly similar to a standard metal key which has a pattern of peaks and valleys along its length. These peaks and valleys must match the tumblers within the lock in order for the lock to open.

With any type of lock, there is always a problem of security. Keys can easily be copied, while many conventional RF and infrared transmitters are far from tamper-proof. One technique is to use a special receiver to intercept and copy the transmitted code. Once copied, the signal can then be re-transmitted to the door lock to gain unauthorised entry.

In fact, this technique was commonly used by car thieves in carparks and proved very effective against early electronic locking systems. It could also be used to open automatic garage doors and gain access to buildings.

### Rolling code security

Modern transmitters now circumvent this problem by changing their code each time they send a signal. So if an unauthorised person captures

the transmitted code, re-sending this code will not unlock the door. This is because the door lock is now expecting a new code based on an algorithm that both the transmitter and receiver have in common.

This code changing technique is commonly called a "rolling code", although it is sometimes also called "code hopping". It renders copying useless and thus provides a very high level of security. It is also virtually impossible to send a correct code without having a valid rolling code transmitter. This is because of the huge number of code variations possible.

Because of its security advantages, a rolling code transmitter forms the basis of the Rolling Code Keyless Entry System described here. In fact, the odds of picking a correct code at random for our rolling code transmitter are one in 1.4 trillion or one in $10^{12}$.

If you want to know more about rolling code transmissions, refer to the separate panel elsewhere in this article.

## Main features

Our new Rolling Code Keyless Entry System comprises a small keyfob-style transmitter and a separate receiver. The transmitter is small enough to be attached to a keyring and has two pushbutton switches, each capable of sending a separate code. Each time one of the switches is pressed, a small indicator LED flashes to indicate that the transmitter has sent its code.

The larger of the two switches activates the alarm functions of the receiver. It arms the unit so that it will sound an alarm should there be unauthorised access.

The alarm functions include an electric door strike control (this allows the door to be opened), two alarm inputs (eg, to monitor doors, windows or other sensors), and an arm/disarm output. The door strike can optionally be set to operate on arming, on disarming or on both.

In addition, an alarm output is provided to sound a siren if required.

The second, smaller pushbutton switch on the transmitter is independent of the alarm. It can be used to operate a separate door strike or some other device connected to the receiver. Such devices can include a light or a siren that can be used as a panic alarm. This can be optionally set to operate momentarily or can be toggled on and off with each switch pressing.

The door strike outputs can be set to operate from between 0-64 seconds, while the inputs can include delayed operation from 0-64 seconds. These delayed inputs allow the alarm to be armed while giving the user enough time to exit the door without setting off the alarm. An identical delay period allows the alarm to be disarmed on entry.

During the exit delay period, the ARM indicator LED in the receiver unit flashes on and off at a 1-second rate. At the end of the exit delay, this LED indicates that the unit is armed by flashing briefly once every second. This conserves power and increases its effectiveness when it comes to attracting attention.

An Acknowledge/Power LED is also included in the receiver. This normally flashes with a very short duty cycle. However, when the receiver picks up a signal from the transmitter, the Ack/Power LED flashes at a very high rate. It also shows if the received code is invalid by momentarily blinking off and on.

If the code is correct, the receiver responds to the signal. The transmission range is about 4m which should be sufficient for most purposes. **Note, however, that it will not work if the IR receiver is in direct sunlight.**

## Setting it up

Before using the Infrared Rolling Code Alarm, both the transmitter and the receiver must be set up correctly. First, each transmitter must be given a separate identity ranging from 1-16. This is selected using link options on the transmitter board but note that no two transmitters should be given the same identity.

Second, the transmitter must be randomised. This changes the initial rolling code and algorithm parameters to ensure that the transmitter code is going to be unique.

The third step involves synchronising the transmitter and receiver. This process involves sending the rolling

## Features & Specifications

### Transmitter

- Rolling code infrared transmission
- Small keyfob style case
- Dual function buttons
- Randomisation of code parameters feature
- Synchronising of parameters feature
- Up to 16 identifications

### Receiver

- 12V operation
- Up to 16 separate transmitters can be synchronised
- Dual function with an independent output
- Two alarm inputs with exit and entry delays
- Two door strike outputs
- Alarm output
- Arm/disarm output and LED indicator
- IR receive acknowledge LED
- Strike 1 operates on arm, disarm or both
- Strike 2 operates independently with momentary operation or toggle output
- Arm output invert option
- Adjustable door strike, entry/exit delay and alarm periods
- 200-code look ahead feature
- Transmitter lockout feature

## Parts List

### Receiver

1 PC board, code 01510071, 61 x 122mm
1 UB3 plastic utility box, 130 x 68 x 44mm
5 2-way PC-mount screw terminal blocks (5mm or 5.08mm pin spacing)
1 SPST vertical mount micro tactile switch with 0.7mm actuator (S1)
3 3-way pin header terminal strips (2.54mm spacing)
4 2.54mm jumper shunts
3 PC stakes
1 25mm length of 0.8mm tinned copper wire
2 10kΩ horizontal trimpots (code 103) (VR1,VR2)

**Semiconductors**

1 PIC16F88-I/P microcontroller programmed with irrcroll.hex (IC1)
1 78L05 low-power 5V regulator (REG1)
1 38kHz infrared receiver (IRD1)
2 BD681 Darlington NPN transistors (Q1,Q2)
2 BC337 NPN transistors (Q3,Q4)
1 16V 1W zener diode (ZD1)
4 1N4004 1A diodes (D1-D4)
1 1N5404 3A diode (D5)
2 3mm red LEDs (LED1,LED2)

**Capacitors**

5 100µF 16V PC electrolytic
3 100nF MKT polyester
3 10nF MKT polyester
1 1nF MKT polyester

**Resistors (0.25W, 1%)**

4 10kΩ
2 2.2kΩ
2 1kΩ
2 680Ω
1 220Ω
2 100Ω
1 10Ω

**Test Components**

4 red LEDs
4 2.2kΩ 0.25W 1% resistors

### Transmitter

1 PC board, code 01510072, measuring 30 x 36mm
1 keyfob remote control case (Jaycar HB-5605 or equivalent)
1 12V A23 car alarm battery (9.5 diameter x 27mm)
2 SPST SMD tactile switches 6 x 6 x 3.85mm (S1,S2)
1 TO-3P transistor silicone insulating washer cut to 20 x 24mm
5 PC stakes
1 25mm length of 0.8mm tinned copper wire

**Semiconductors**

1 PIC16F828A-20/SO 18-lead SOIC microcontroller programmed with irxmroll.hex (IC1)
1 MC78M05 DPAK 5V regulator (REG1)
1 MMBT100 SOT-23 SMD NPN transistor (Q1)
1 MMBT200 SOT-23 SMD PNP transistor (Q2)
2 1N4148 diodes (D1,D2)
1 3mm infrared emitting LED (LED1)
1 green gull wing style surface mount LED (2.2 x 2.2mm) (LED2)

**Capacitors**

2 1µF monolithic ceramic
1 100nF monolithic ceramic

**Resistors (0.25W, 1%)**

2 10kΩ
3 1kΩ
2 22Ω

code parameters to the receiver, as described next month. You can synchronise from 1-16 transmitters, provided each has a different identity.

Also included is a facility to prevent any or all transmitters from operating the receiver once they have been synchronised. This "lockout" feature can be useful if a transmitter has been lost and you no longer want it to work with your alarm system.

A transmitter identity can be locked out individually but if you don't know the identity of a lost transmitter, all identities can be locked out. The transmitters that are to be used with the receiver are then re-synchronised.

## Transmitter circuit

OK, so much for the background details. Let's now take a look at how the circuit works, starting with the transmitter – see Fig.1.

IC1, a PIC16F628A microcontroller, forms the heart of the transmitter circuit. The circuit might look quite simple but there are a lot of "smarts" hidden inside the PIC micro, including the software necessary to generate the rolling code.

Under normal conditions, switches S1 & S2 are open circuit and transistor Q2 is off, so no power is applied. This is done to ensure long battery life. If power were continuously applied, the current drawn from the battery would be around 4mA because of the quiescent current of the 5V regulator.

Conversely, pressing either S1 or S2 connects the 12V battery to the input of regulator REG1 via diode D1 or D2. A 22Ω resistor is included in series between the battery and the switches to limit the initial charging current into the 1µF bypass capacitor at REG1's input. This minimises wear on the switch contacts.

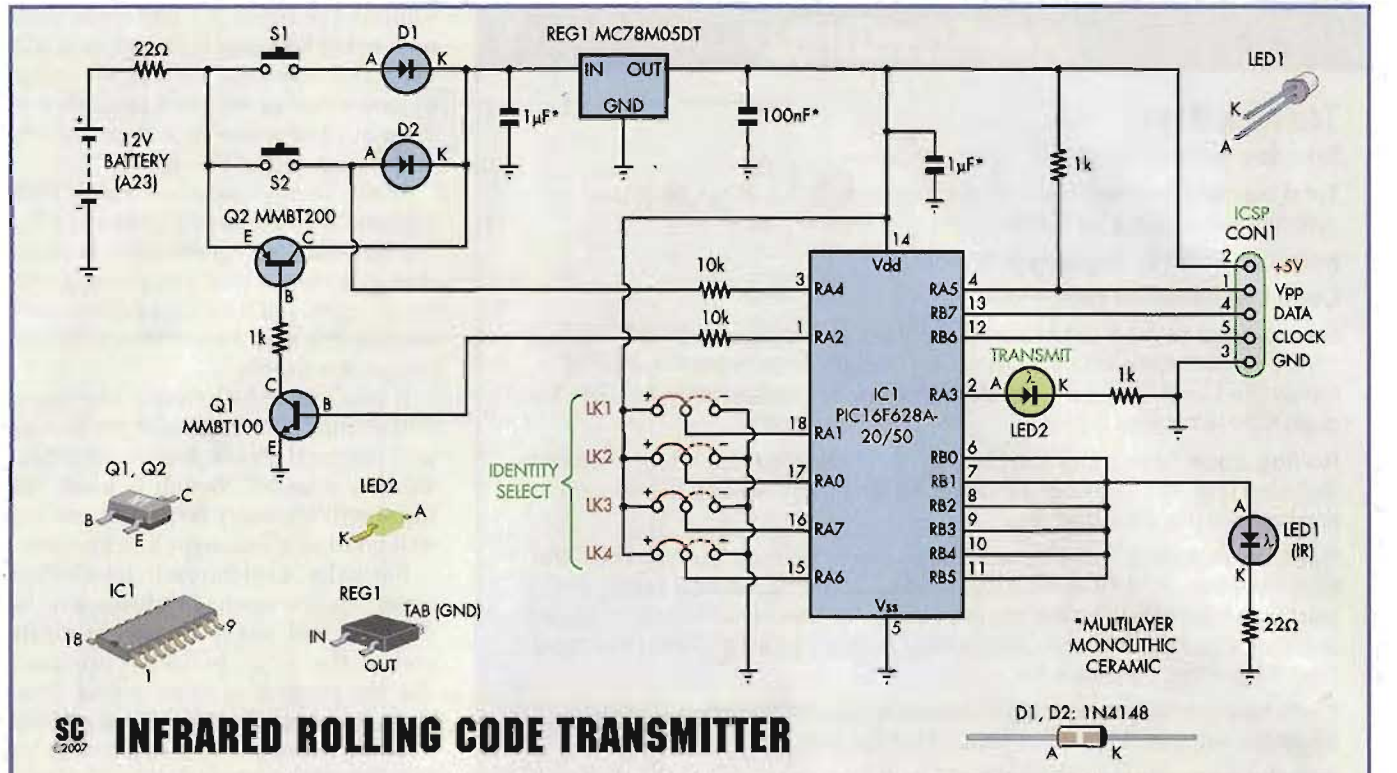
When power is applied to REG1's input, its output delivers a regulated +5V rail to IC1. As a result, the micro powers up and runs its internal software program.

One of the first things the program does is check which switch was pressed (this happens after a short delay to make sure the switch is fully closed). In operation, the program can decide if S1 or S2 is pressed because of the 10kΩ resistor connected between S2 and the micro's RA4 input.

It works like this. Initially, RA4 is set low by the program. This pin is then made open circuit so that it can be pulled high if switch S2 was closed. However, if S1 was closed instead, the RA4 pin will stay at 0V. By checking the voltage on RA4, the program can thus determine which switch was pressed and initiate the correct function codes for that switch.

The 10kΩ resistor is necessary to limit the current into the internal clamping diodes at RA4 when S2 is closed. In practice, the positive clamp diode will conduct, clamping the RA4 input to 0.6V above the +5V supply. This protects the input from damage.

Diodes D1 & D2 protect the regulator from reverse polarity should the battery be inserted the wrong way around. These diodes also isolate the switch outputs from each other, so that the RA4 input will only go high if S2 is pressed. If S1 is pressed, the 12V at REG1's input reverse biases D2 and so




## INFRARED ROLLING CODE TRANSMITTER

**Fig.1: a PIC16F628A microcontroller forms the heart of the transmitter circuit. It contains all the software necessary to generate the rolling code and drives an infrared LED (LED1).**

is blocked from reaching RA4.

Next, the program sets RA2 at pin 1 of the micro high. This output drives the base of NPN transistor Q1 via a 10kΩ resistor. As a result, Q1 switches on and this in turn switches on transistor Q2.

This action latches the supply to regulator REG1, even if switch S1 or S2 is released. This is necessary to allow time for the rolling code calculations to be made and stored without interruption, otherwise the code may become corrupted. It also ensures that the rolling code is transmitted in its entirety.

The next stage in the program involves calculating the code and storing the values. This calculation is based on the previously transmitted code and uses an internal algorithm. Once calculated, the new code appears at outputs RB0-RB5 which in turn drive an infrared LED (LED1). The 22Ω resistor in series with LED1 limits the current to a safe value.

In operation, LED1 is driven using 100mA pulses at a rate of 38.46kHz. A high (or a "1") is transmitted as a 512µs-long burst of 38.46kHz signal, followed by 512µs of no transmission. Conversely, a low (or a "0") consists of a 512µs period of no transmission followed by a 512µs burst of 38.46kHz signal.

LED2 is the Transmit LED and is driven by output RA3 during code transmission. Basically, RA3 goes high each time there is a "1" in the transmitted code, and low each time there is a "0". As a result, LED2 flashes to mimic the transmission code.

## Transmitter identity

Transmitter identity is selected using the LK1-LK4 link connections to RA1, RA0, RA7 & RA6. As shown, each individual input can be connected to either the +5V supply or the ground supply (0V) but not to both or the supply will be shorted. The number of possible combinations is 16.

Each of these inputs is initially tied to +5V on the PC board (via thin PC tracks) and this selection is Identity 1. The other 15 identities are selected by breaking one or more of these connections to the +5V rail and connecting them instead to an adjacent 0V rail.

We'll talk more about this in the construction.

## In-circuit programming

Five-pin header CON1 is provided on the circuit to allow for In-Circuit Serial Programming (ICSP) of IC1 using a PIC programmer. Alternatively, we have developed a surface-mount converter board that will allow IC1 to be programmed directly using a PIC programmer. We'll publish the details on this next month.

The ICSP connections on the transmitter are also used to run the randomisation and synchronisation functions using a bridge between pins 3 & 5 and 3 & 4 respectively.

IC1 runs at a nominal 4MHz, as provided by an internal oscillator. This oscillator has a 1% tolerance and its accuracy is sufficient for this application (ie, there's no need for a crystal oscillator). However, because the oscillator frequency can vary with temperature, we have included a means for the receiver to lock onto the transmitter's clock rate, so that variations over a long time period do not matter.

By the way, the transmitter uses several surface-mount components so that the circuit will fit into a small keyfob case. These surface-mount parts include IC1, REG1, Q1, Q2, LED2, S1 & S2. The remaining parts are standard through-hole component

## Specifications

### Transmitter

**Standby current:** 0mA

**Total transmit current:** rolling code transmission = 35mA for 80ms; synchronise = 35mA for 100ms; randomisation = 10mA.

**Infrared transmit frequency:** 38.46kHz

**Code transmission rate:** 1.024ms

**Encoding:** a high (or a 1 bit) is transmitted as a 512µs burst of 38.46kHz infrared signal followed by 512µs of no transmission. A low (or 0 bit) is transmitted by a 512µs period of no transmission followed by a 512µs burst of 38.46kHz infrared signal.

**Rolling code:** sends four start bits, an 8-bit identifier, the 48-bit code plus four stop bits. The start bits include a 16.4ms gap between the second start bit and the third start bit.

**Synchronise code:** sent as two blocks. Block 1 sends four start bits, the 8-bit identifier, a 32-bit seed code and four stop bits. Block 2 sends four start bits, a 24-bit multiplier, the 8-bit increment and 8-bit scramble values, and four stop bits. The start bits include a 16.4ms gap between the second start bit and the third start bit.

**Code randomisation:** alters the multiplier values, the increment value, the scramble value and the seed code at a 40µs rate.

**Infrared transmission range:** 4m

### Receiver

**Supply Current:** 7.6mA typical when armed and with no external devices powered.

**Strike 1 period:** adjustable from 0-64 seconds in 0.25s steps approximately.

**Strike 2 period:** adjustable from 0-64 seconds in 0.25s steps approximately.

**Input 1 delay:** adjustable from 0-64 seconds in 0.25s steps approximately for exit and entry delays.

**Input 2 delay:** adjustable from 0-64 seconds in 0.25s steps approximately for exit and entry delays.

**Alarm period:** adjustable from 0-128 seconds in 0.50s steps approximately

types that are small enough to fit onto the PC board.

## Receiver circuit

Refer now to Fig.2 which shows the receiver circuit. It's built around infrared receiver IRD1 and PIC microcontroller IC1, the latter operating at 4MHz to match the transmitter's frequency. Once again, much of the complexity is hidden by the software programmed into the microcontroller.

IRD1 only has three leads but inside it comprises a complete infrared detector and processor. First, it receives the 38kHz infrared pulse signal from the transmitter and amplifies this to a constant level. This signal is then fed to a 38kHz bandpass filter to remove any 50Hz or 100Hz mains signal and other noise. It then demodulates the signal to produce a serial data burst at IRD1's pin 1 output.

This serial data signal from IRD1 is fed to the RB4 input of IC1 via a 100Ω resistor. A 1nF capacitor filters out any transients.

IRD1 is powered from the receiver's +5V supply rail. A 100Ω resistor and a 100µF capacitor provide supply decoupling and filtering, to prevent the receiver from producing false signals due to power line changes.

As well as the IR receiver, there are two other inputs to the PIC microcontroller. These are alarm sensor inputs – Input 1 & Input 2 – and these connect to the RB5 and RB6 inputs of IC1 via 2.2kΩ resistors. Each input is also bypassed using a 100nF capacitor to filter out transients and thus prevent false triggering of the alarm.

When these inputs are open, both RB5 and RB6 are held high (ie, at +5V) via internal pull-up resistors. In practice, this means that you can use normally-open (NO) or normally-closed reed switch and magnet assemblies to trigger the inputs.

If you use an NO switch, the input will normally be high and the system will trigger if a switch is closed. Conversely, if an NC switch is used, the input will normally be pulled low but will go high if the switch is opened.

Basically, any change in level when a reed switch opens or closes will be detected and sound the alarm at the end of the entry period – provided that the receiver is in its armed state. Note, however, that the alarm will not sound if the receiver is still within its exit delay period.

## Door strike outputs

When an IR signal transmission is received, the output from IRD1 is processed by IC1. This then drives Darlington transistors Q1 & Q2 as appropriate to control the door strike outputs (ie, Strike1 & Strike2).

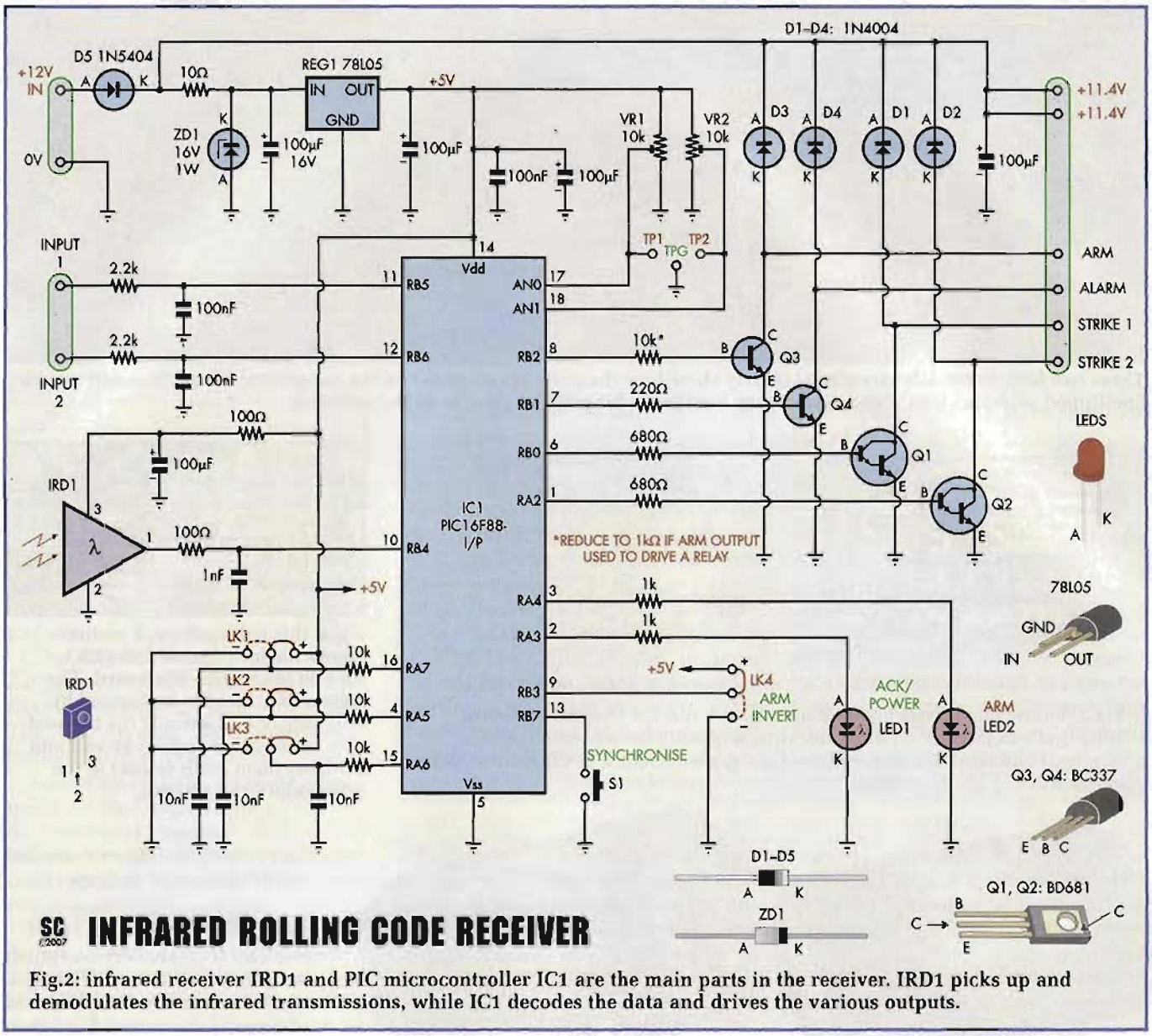
As shown, Q1 & Q2 are driven via 680Ω resistors from IC1's RB0 and RA2 outputs respectively. Diodes D1 & D2 clamp the voltage produced by the door strike solenoid to the supply rail when the transistor is switched off.

Transistors Q1 & Q2 are both BD681 Darlington types and can be used to drive loads up to 1.5A. A typical electric door strike only draws about 800mA at 12V.

The other two outputs are the Alarm & Arm outputs and these are controlled by transistors Q4 & Q3 (both BC337) respectively. Q4 is driven by IC1's RB1 output via a 220Ω current limiting resistor. However, the base current is sufficient for the transistor to remain fully saturated for a 200mA load and this is ideal for many piezo sirens.

Similarly, transistor Q3 is driven via a 10kΩ resistor from IC1's RB2 output. Q3's collector provides the Arm output and this can be used as a toggle output to set a second alarm system.

Typically, you would use a 1kΩ pull-up resistor between the Arm output and the +12V rail, so that the




# SC INFRARED ROLLING CODE RECEIVER

**Fig.2: infrared receiver IRD1 and PIC microcontroller IC1 are the main parts in the receiver. IRD1 picks up and demodulates the infrared transmissions, while IC1 decodes the data and drives the various outputs.**

level can swing between 0V and 12V. Alternatively, Q3's collector could be used to drive a relay coil. In this case, the 10kΩ base resistor will need to be reduced to 1kΩ so that the transistor can remain in saturation while driving a 285Ω 12V relay coil.

The unit can be optionally configured with Q3 either on or off when armed. This is set using link LK4.

When LK4 is in the "+" position, Q3 is on when the unit is armed and off when disarmed. In this case, the RB3 input is held at +5V via an internal pull-up resistor within IC1.

Moving LK4 to the "-" position pulls RB3 to ground and changes the sense of the Arm output. In this case, Q3 is off when the unit is armed and on when disarmed.

LED 2 indicates the state of the unit. It's driven from the RA4 output of IC1 via a 1kΩ resistor and flashes when the unit is armed.

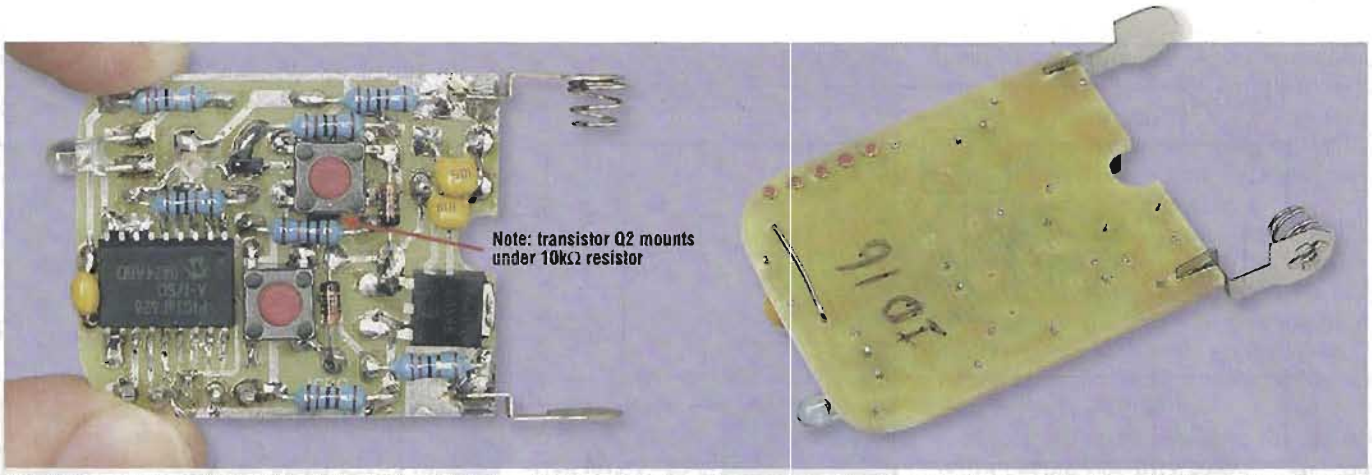
There are two different flash styles. During the entry and exit delay periods, the LED flashes with a 50% duty cycle (ie, it is on for half the time and off for half the time). However, at the end of the delay period, it flashes on for only 4% of the duty cycle (ie, each flash is very brief).

## Other link options

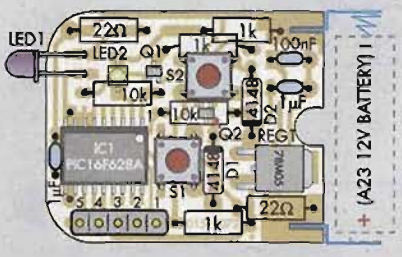
Links LK1, LK2 & LK3 are included to provide further options. For example, LK1 can be tied to either the +5V rail or to 0V, or it can be left open. These three options determine how the Strike1 output operates. Basically, Strike1 can be set to operate when the unit is armed, when it is disarmed or on both arming and disarming.

In operation, the software programmed into the PIC micro decides where the link is inserted by running a few tests. First, it takes the RA7 output high (5V) and then sets the RA7 pin as an input to read the voltage. If the voltage is now low, then the link must be in the "-" position. However, if the input remains high, then the link is either in the "+" position or is open circuit (it remains high when the link is open because of the charge on the associated 10nF capacitor to ground).

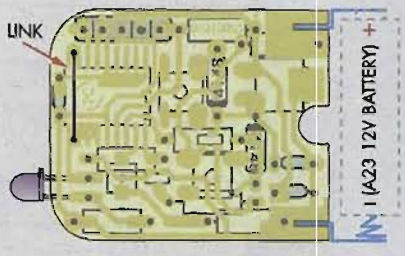
To test if the link is in the "+" position or open, the RA7 pin is made an output again and is driven low (to 0V). The RA7 pin is then changed




These two larger-than-life-size photos clearly show how the parts are mounted on the transmitter board. You will need a fine-tipped soldering iron (2mm diameter or less) and a magnifying glass to do the assembly.




TRANSMITTER BOARD – COPPER SIDE




TRANSMITTER BOARD – NON COPPER SIDE

Fig.3: follow these parts layout diagrams to build the transmitter board. Note that you have to set the transmitter's identity before installing IC1 (see text) and don't forget transistor Q2 – it goes under a 10kΩ resistor, just below S2.

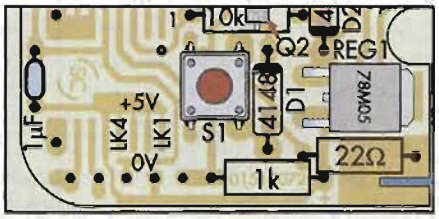



Fig.4: this enlarged track section shows the locations of links LK1-LK4 on the transmitter board. The transmitter identity is changed by breaking one or more of the thinned link connections to the +5V rail and bridging them (with solder) to the adjacent 0V rail instead.

to an input and the level checked again. If the voltage is now high, then the link must be in the "+" position. Conversely, if the voltage is low, then the link is open.

The 10kΩ resistor in series with RA7 is there to prevent shorting when this pin is taken high and low with a link in position.

LK2 sets Strike2's operation for either momentary operation or for toggle operation. This link pulls the RA5 input either to +5V when it is in the "+" position (momentary) or to 0V when it is in the "-" position (toggle). Note that this link cannot be left open because the RA5 pin can only be used as an input.

LK3 is used in conjunction with trimpots VR1 and VR2 to set the various time periods. These include the Strike1 and Strike2 momentary on periods, the entry and exit delays for Input1 and Input2, and the alarm period.

As shown on Fig.2, trimpots VR1 & VR2 are connected across the 5V supply and their wipers connect to analog inputs AN0 and AN1 respectively. The voltage applied to each analog input is converted to a digital value within the software and it is these values that determine the timeout periods.

## Capacitor Codes

| Value | µF Code | IEC Code | EIA Code |
|---|---|---|---|
| 100nF | 0.1µF | 100n | 104 |
| 10nF | .01µF | 10n | 103 |
| 1nF | .001µF | 1n0 | 102 |

## Synchronise switch

Switch S1 is the Synchronise switch and this connects to the RB7 input. This input is normally held high via an internal pull-up resistor but when S1 is closed, it pulls RB7 to 0V.

Basically, S1 is used to synchronise the receiver with the transmitter. It is also used when setting the time periods. In addition, if S1 is closed during power-up, it selects the transmitter identity lockout function.

## Power supply

Power for the circuit is from a 12V supply such as a battery or DC plugpack. Diode D5 provides reverse

## Resistor Colour Codes (Transmitter)

| ❑ | No. | Value | 4-Band Code (1%) | 5-Band Code (1%) |
|---|---|---|---|---|
| ❑ | 2 | 10kΩ | brown black orange brown | brown black black red brown |
| ❑ | 3 | 1kΩ | brown black red brown | brown black black brown brown |
| ❑ | 2 | 22Ω | red red black brown | red red black gold brown |

**Table 1: Transmitter Identity**

| Identity | LK1 | LK2 | LK3 | LK4 |
|---|---|---|---|---|
| 1 | + | + | + | + |
| 2 | + | + | + | - |
| 3 | + | + | - | + |
| 4 | + | + | - | - |
| 5 | + | - | + | + |
| 6 | + | - | + | - |
| 7 | + | - | - | + |
| 8 | + | - | - | - |
| 9 | - | + | + | + |
| 10 | - | + | + | - |
| 11 | - | + | - | + |
| 12 | - | + | - | |
| 13 | - | - | + | + |
| 14 | - | - | + | - |
| 15 | - | - | - | + |
| 16 | - | - | - | - |

The keyfob case is supplied with the key switch covers mounted as shown here. This assembly must be removed.

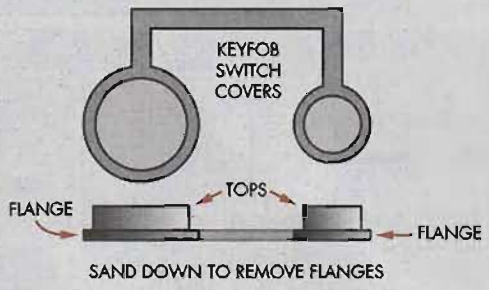



Fig.5: once the switch covers have been removed, the flanges are ground down using 180-grit sandpaper, so that only the tops remain (see text).

polarity protection and is rated at 3A so that it can handle the currents that may be drawn by an electric door strike and siren.

The 10Ω resistor and zener diode ZD1 provide transient protection, with the zener clamping voltages over 16V. The 10Ω resistor limits the current through ZD1 to a safe level.

Following ZD1, the supply is filtered using a 100µF capacitor and applied to 3-terminal regulator REG1. The resulting regulated +5V rail is then used to power IC1 and the infrared receiver (IRD1).

Power on/off indication is provided by LED1 which also acknowledges the infrared signal. Normally, LED1 flashes with a 4% duty cycle about twice per second. However, when an infrared signal is received, it flashes at the infrared reception rate.

LED1 also flashes with an even duty cycle for a short time at the end of synchronisation and if the infrared signal is incorrect.

## Construction

The Infrared Keyless Entry Alarm is built on two PC boards: a receiver board coded 01510071 and a transmitter board coded 01510072. We'll start with the transmitter assembly which is the trickier of the two.

In order to fit in the keyfob case, the transmitter board measures just 30 x 36mm and uses lots of surface-mount components. However, these are not too difficult to solder in, provided you have a soldering iron tip that is just 2mm in diameter or finer. A magnifying glass (or, preferably, a "maggie lamp") is also required to check your soldering, while a length of 1.5mm de-soldering braid (solder wick) would also be useful for cleaning up any excess solder that may flow between connections.

Fig.3 shows the parts layout on the PC board. The first step is to check the PC board carefully for any breaks in the copper or shorts between tracks. Repair any faults that you do find (rare these days), then check the shape of the board. It should have a curved front edge and a small circular cut out at the other end. In addition, there should be two slots for the battery clips.

Next, check that the PC board fits neatly into the base of the keyfob case. If it does not fit, it's just a matter of filing it neatly along the edges until it does.

## Setting the identity

**Before mounting any of the parts, it's first necessary to set the transmitter's identity but only if more than one transmitter is to be used. If more than one transmitter is used, then each will require a unique identity.**

As supplied, the PC board initially

Above: the finished transmitter board inside its keyfob-style plastic case. Power comes from a 12V A23 car alarm battery. Note how the keyswitch covers are mounted on the lid, using a 20 x 24mm silicone washer – see text.

Right: the two keyswitch covers are attached to the 20x 24mm silicone washer as shown here. Use silicone sealant to "glue" them in place. The keyfob lid can be used as a template to position them correctly.

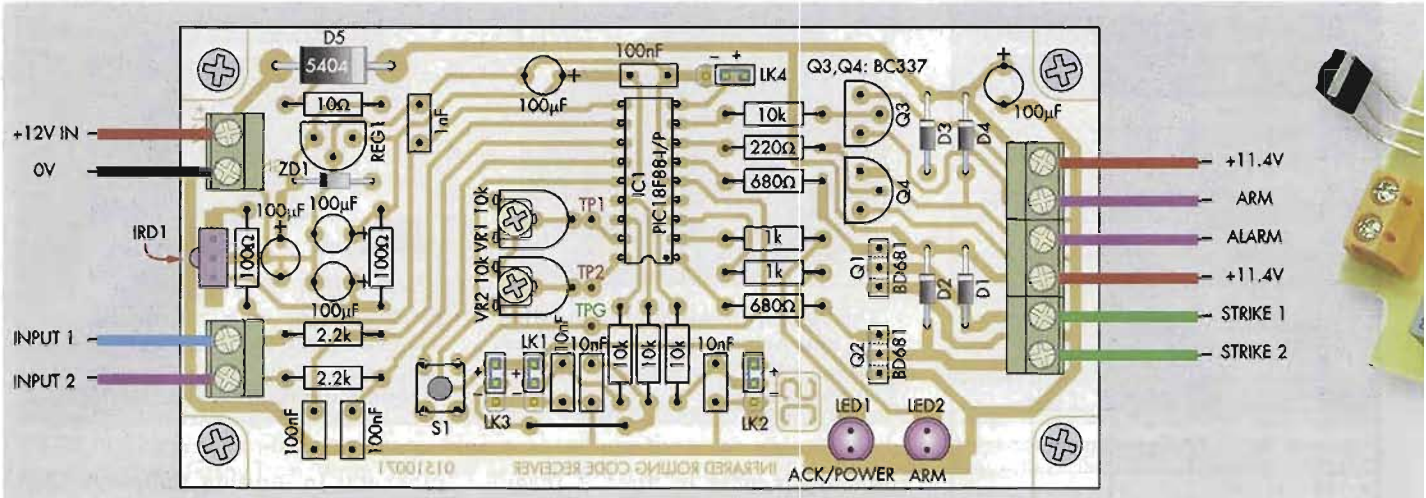



**Fig.6: follow this diagram to mount the parts on the receiver board. Use a socket for the PIC microcontroller and take care to ensure that all polarised parts are correctly orientated. The infrared receiver module (IRD1) can either be mounted on the board (as in the prototype) or connected via shielded cable (see diagram next month).**

ties links LK1-LK4 to the +5V supply rail. This is Identity1, or ID1. If only one transmitter is to be used, then you don't have to do a thing – just leave it at the default identity (ID1).

If you do wish to change the identity, it's just a matter of altering one or more of the links as shown in Table 1. You do that by breaking the link's thinned connection to the +5V track and connecting it to the adjacent 0V track instead via a small solder bridge.

Make sure, however, that a link connection is not made to both the +5V and 0V tracks. We have labelled the +5V connection with a plus (+) sign and the 0V connection with a minus (-) sign.

**It is important to select the identity now because the +5V track section cannot be accessed when IC1 is in place.** The +5V connections should only be broken with a sharp craft knife and, once broken, should not be resoldered. That's because IC1 would no longer sit properly on the board, making it difficult to solder its pins.

The selected identity should be marked on the back of the PC board using a marker pen. For example, if the identity is 2, write ID2 on the PC board. This number can also be written on the back of the keyfob transmitter case, in the indentation provided.

If you are building the unit from a kit, then IC1 will be supplied pre-programmed. If not, you will have to program the PIC yourself using a suitable programmer. As previously mentioned, we have provided two programming options, the first of which is to use the in-circuit programming connector on the PC board.

Alternatively, you can build and use the surface mount adaptor board to be described next month, so that IC1 can be programmed out of circuit.

## Parts assembly

Except for a single wire link, all parts for the transmitter mount on the copper side of the PC board. Don't install the link yet though – that step comes after you install IC1.

To install IC1, position it on the board with its pin 1 at top right – see Fig.3 (pin 1 is indicated by a small adjacent dot in the body of the IC). Carefully adjust it so that its pins line up with the tracks and use a clothes peg (or some other small spring-clamp) to hold it in position.

That done, solder a couple of diagonally opposite pins, check that everything is correct, then remove the peg and carefully solder the remaining pins.

The main thing to watch out for here is unwanted solder bridges between adjacent tracks. If this does happen, use some solder wick to draw up the excess solder to clear the short. A magnifying glass will be handy here to inspect your work.

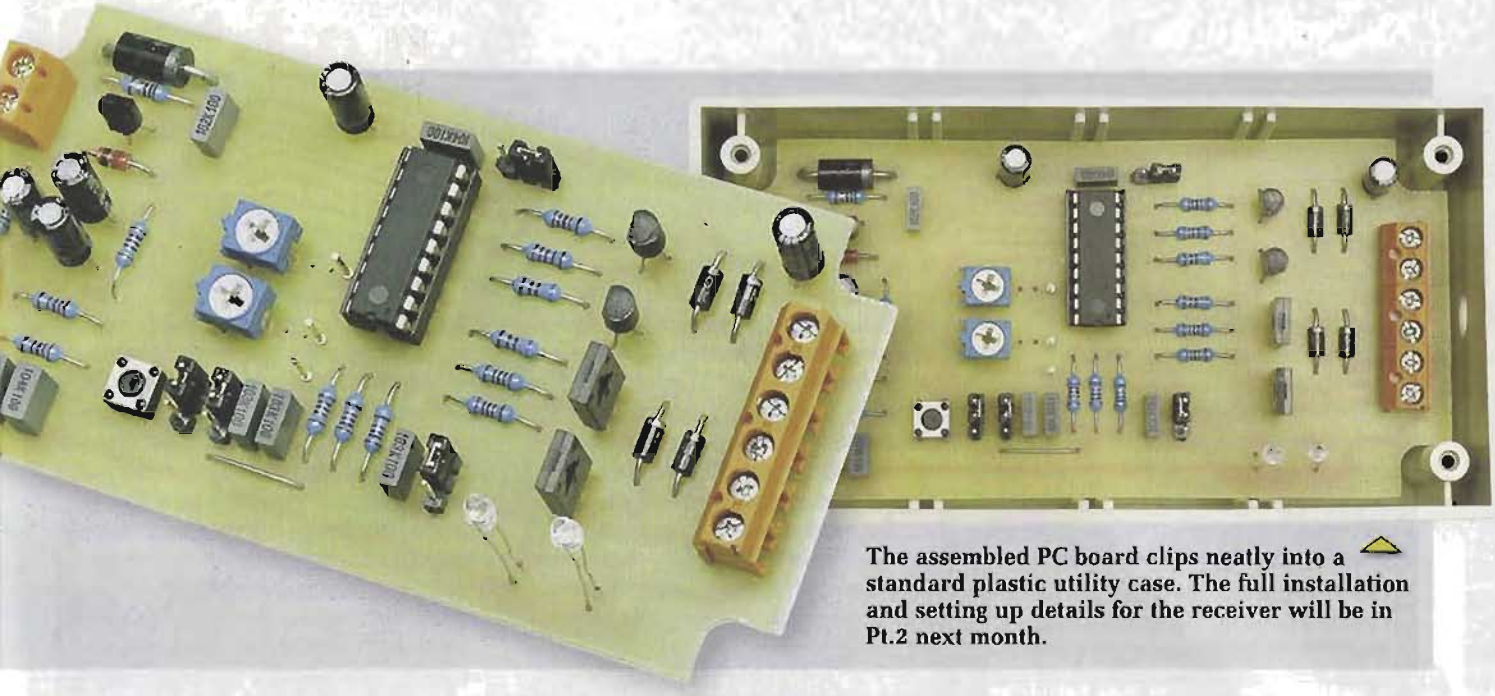
Note that pins 6-9 and 10-11 are connected together anyway, so solder between these pins is OK.

Once the IC is in, you can install the link beneath it on the other side of the board. This link must sit flat against the board, otherwise the board will not sit down in the case correctly.

The remaining surface mount components – Q1, Q2, LED2 & REG1 – can

## Resistor Colour Codes (Receiver)

| ❑ | No. | Value | 4-Band Code (1%) | 5-Band Code (1%) |
|---|---|---|---|---|
| ❑ | 4 | 10kΩ | brown black orange brown | brown black black red brown |
| ❑ | 2 | 2.2kΩ | red red red brown | red red black brown brown |
| ❑ | 2 | 1kΩ | brown black red brown | brown black black brown brown |
| ❑ | 2 | 680Ω | blue grey brown brown | blue grey black black brown |
| ❑ | 1 | 220Ω | red red brown brown | red red black black brown |
| ❑ | 2 | 100Ω | brown black brown brown | brown black black black brown |
| ❑ | 1 | 10Ω | brown black black brown | brown black black gold brown |



**The assembled PC board clips neatly into a standard plastic utility case. The full installation and setting up details for the receiver will be in Pt.2 next month.**

now be soldered in place. **Transistor Q1 has an N1 label on its top, while Q2 has an N2 label instead.** These numbers relate to the MMBT100 and MMBT200 types respectively. Don't get them mixed up.

## Installing the semiconductors

The orientation of the two transistors is obvious – they have one pin on one side of the body and two on the other side. REG1 has a GND tab plus IN and OUT pins that must be soldered to the PC board. The central pin between the IN and OUT pins is left unconnected.

**Be careful with the orientation of LED2 – its cathode lead is the longer of the two.**

Next, solder in switches S1 & S2, then install five PC stakes for the ICSP header. These pins are inserted from the non-copper side of the PC board and soldered in position. The pins are then trimmed on the copper side to 3mm in height. On the underside, they are trimmed and filed to 0.5mm.

The standard components can now be installed. These must be mounted flat against the PC board or as close to it as possible in the case of the 10kΩ resistor that straddles Q2. Take care with the orientation of diodes D1 & D2 and note that the tops of the three monolithic capacitors must be no more than 4mm above the PC board.

In particular, the two capacitors near REG1 can be laid over at about 45°, while the one adjacent to IC1 needs to have its leads adjusted so it can be pushed down onto the PC board far enough to meet the 4mm height requirement.

Cut all the leads beneath the PC board (ie, on the non-copper side) flush with the surface.

LED1 can go in next. Its anode lead is the longer of the two (unlike LED2) and this lead must go towards IC1. To mount it, first bend its leads down by 90° exactly 2mm from its body, then insert the leads into the PC board. Finally, push the LED all the way down onto the PC board, solder the leads and cut them flush with the underside.

Note that a small circular notch is required in the rim of the keyfob base for the LED to sit in. This can be made using a small rat-tail file. When this notch has been made, file a matching notch in the top half of the keyfob case.

## Battery terminals

The battery terminals are installed by first placing the PC board in the base of the case. That done, the terminals are slid into position and soldered. Make sure that the terminal with the spring is located as shown in Fig.3.

## Switch cover modifications

The key switch covers that are supplied with the keyfob case have to be modified to suit the two switches on the PC board.

As supplied, the two switch covers are already secured in place in the keyfob lid. This assembly must be removed and the covers carefully ground down to 1.5mm thick – see Fig.5. This is done by placing some 180-grit sandpaper onto a flat bench and sanding the switch covers until they are flat on their base.

That done, cut out a 20 x 24mm rectangular piece from a silicone TO-3 washer (20 x 24mm) to make a new switch cover assembly. It's then simply a matter of attaching the switch covers to this washer using silicone sealant – see photo. Use the keyfob lid as a template to position the covers correctly.

## Receiver assembly

Now for the receiver. As usual, start by checking the PC board for any defects. Check also that the hole sizes for the screw terminal blocks are correct and enlarge them if necessary.

That done, check that the PC board fits inside the specified utility case. File the board edges to get it to fit if necessary but don't file them too much, otherwise the board will not lock correctly into the wall slots.

Fig.6 shows the assembly details. Install the wire link first, then install the resistors. The accompanying table shows the resistor colour codes but you should also check them using a digital multimeter.

The diodes and the IC socket can go in next, taking care to orient each with the correct polarity. Follow these with the capacitors, again making sure that the electrolytics go in correctly. The three PC stakes for TP1, TP2 & TPG can then be installed.

Depending on your requirements, LEDs 1 & 2 can either be mounted directly on the PC board or mounted

# Frequently Asked Questions

One question that's often asked about rolling code systems is what happens if the transmitter is out of range and one of the transmit switches is pressed? Will the receiver still work when the transmitter is later brought within range and the button pressed again?

This question is asked because the code the receiver was expecting has already been sent and the transmitter has rolled over to a new code. So how does the system get around this problem?

The answer to this is that the receiver will acknowledge a signal that is the correct length and data rate but it will not trigger unless it receives the correct code. So if the signal format is correct but the code is incorrect, the receiver then calculates the next code that it would expect and checks this against the received code. If the code is now correct the receiver will unlock the door.

If the code is still incorrect, the receiver calculates the next expected code and will do this up to 200 times. If none of these are correct, the receiver keeps its original code but it will not trigger. In fact, the only way to trigger the receiver after this is to re-synchronise it to the transmitter.

Of course, a second transmitter will still operate the receiver (provided they have been synchronised in the first place). That's because this transmitter has a different identity and a different code to the other transmitter.

## Automatic synchronisation

Some rolling code transmitters systems offer automatic synchronisation if the transmitter and receiver lose sync. In these systems, the receiver includes a code "look-ahead" feature as described above but the number of look-ahead codes is usually limited to fewer than 200. What happens is that if the code is not recognised after all the look-ahead calculations have been made, the receiver changes its synchronisation method.

Basically, the receiver requires two separate transmission codes before restoring correct operation. On the first transmission, it calculates the next code it should receive using this received code as the basis for calculation. If the second code sent by the transmitter is the same as the code that was calculated, the receiver operates.

The drawback of this latter scheme is somewhat less security since, in theory, two successive transmission codes could be intercepted and recorded. These codes could then be re-transmitted to synchronise and thus trigger the receiver.

## Calculating the code

Another question that's often asked is how does the receiver know which code to expect from the transmitter, since this changes each time?

The answer to this is that the transmitter and the receiver both use the same calculation to determine the next code. They also both use the same variables in the calculation and these variables tend to be unique values that no other transmitter uses.

For example, if the calculation for consecutive codes requires the original calculated code to be multiplied by 100 and the number 7 added to it, then both the transmitter and receiver will use these numbers to perform the calculation.

Without knowing both the multiplier and the increment value, it would be very difficult to predict the next code. This is particularly true because of the very large numbers involved. The values quoted for the multiplier and increment value are not as simple as 100 and 7 but are 24 bits and eight bits respectively in length.

In addition, the code length is 48 bits with as many as $2.8 \times 10^{14}$ combinations. This reduces by a factor of 200 because of the look ahead feature to a 1 in $1.4 \times 10^{12}$ chance of striking the correct code – still impossibly long odds.

## Code scrambling

A further complication with the transmitted code is that the code is not necessarily sent in sequence. There are also 32 possible scrambling variations that can be applied to the code.

What if the transmitter sends two consecutive codes that are the same and the code is intercepted and re-transmitted to open the lock? This is highly improbable and our rolling code transmitter has safeguards to prevent the same code appearing twice in succession. For each code calculation, a comparison is made between the current and last code. If the code is the same, the code is recalculated after an increment of the code value to ensure successive code calculations diverge. It is this new code that is transmitted.

The receiver performs the same recalculation so that the new code will be accepted.

Another question concerns the use of different transmitters. Does each transmitter use the same rolling code calculation and if so, wouldn't the receiver lose its synchronisation if several transmitters were used? The answer is that the receiver will not lose synchronisation, even if one of the transmitters is not generally used. This is because each transmitter operates independently from the others.

Only 16 transmitters can be used with a given receiver and each must have its own different identity from 1-16. The identity is built into each transmitter and synchronisation is required for each transmitter.

The codes sent by each transmitter are different and the code includes the transmitter identity value. The receiver has 16 different rolling code and calculation parameters, and so each transmitter is treated independently.

externally and connected using wire leads. Be sure to mount each LED with its cathode lead (the shorter of the two) towards the lower edge of the PC board.

Similarly, IRD1 can either be mounted directly on the PC board or connected using twin-core shielded cable (see diagram in Pt.2 next month).

Trimpots VR1 & VR2 and the 3-way and 2-way pin headers for LK1-LK4 are next on the list. That done, install REG1 and transistors Q1-Q4. Q1 & Q2 must be installed with their metal faces towards IC1.

Finally, complete the board assembly by installing switch S1 and the screw terminal blocks. Note that the 6-way terminals at the righthand edge of the PC board are made up using three 2-way blocks. These are joined by sliding their dovetail joints together before installing them on the PC board.

That's all we have space for this month. Next month, we'll complete the construction and describe the installation and setting-up procedures, including setting the entry and exit delays. We'll also describe the optional SOIC adapator board, so that you can program the PIC microcontroller out of circuit. SC

# SERVICEMAN'S LOG

## Fix it in the carpark!

**Ever tried to fix a rear projection TV set in a carpark? That's precisely the silly situation I got myself into recently, all driven by a terrible need to earn money.**

I was asked to go and fix a Sony TV in someone's garage. Well, I have been asked to do weirder things than that before but I gently pointed out that it would be easier (and hence cheaper) if he brought it in.

My client apologised but said it just wouldn't fit in his van and he couldn't lift it by himself. How large could this set be? It turned out to be 154cm (61-inch) rear projection TV measuring 1336 x 1519 x 647mm (W x H x D) – no mere portable!

The set was, in fact, a 1997 Sony KP-E61SN11 (SCC-K64C-A RG-1 chassis). Its problem was that it took hours for a picture to come on. But why was it in the garage? Simple – it wouldn't fit into his tiny flat!

The other major drama was that he lived near the sea. Why is that a drama? Well, this set generates 34kV and supplies it to three picture tubes at up to 3mA. And that often means insulation problems.

Anyway, reluctantly, off I went to this guy's small garage at the back of his unit. However, in order to gain the necessary access, we had to first pull the TV out of the garage so that I could work on it in the carpark. This was, at best, quite unsatisfactory.

I switched the set on, hoping that the voltage drop on his incredibly long extension cord wouldn't have any effect! The set tried hard to come on but in the end just the red LED was left flashing. Unfortunately, this set was too old to have meaningful error codes that could actually be read.

Initially, I tried disconnecting the EHT to the HV block splitter but it made no difference. There was no point persisting in the carpark – I removed the power supply and called it quits.

Back at the workshop, I examined the power board and discovered that pin 3 (-135V) of socket CN6010 was corroded and pitted. I cleaned this up, soldered a few suspect dry joints and replaced C6030 (0.039µF 1kV) which is on pin 3 of T6005. I also replaced R6009 and R6010 (270kΩ) – both start-up resistors – as they were corroded.

Next, I connected a 100W globe across the +135V rail and shorted +7V STBY (pin 1) to Power Control (pin 3) of connector CN6008. I then connected 240V AC directly to CN6007 and the power supply came on quickly and cleanly, to give the correct voltage outputs.

Convinced that I had fixed the power supply, I returned to the set. However, it wasn't going to be that

### Items Covered This Month

- Sony KP-E61SN11 (SCC-K64C-A RG-1 chassis) rear projection TV set
- Sony KV-HX32M31 TV set (AX-1 chassis)
- Sony KV-HR32M31 TV set (AX-1 chassis)
- Grundig Lenaro 92 TV set (MFW92-6110/9 DVD CUC1937 chassis)

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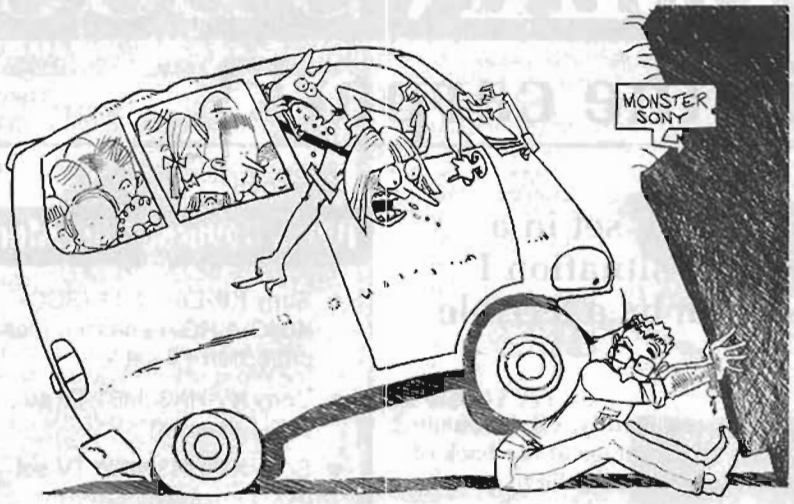


...BUT WAS THEN FORCED TO ABANDON THE WHOLE EXERCISE WHEN ANOTHER UNIT OWNER WANTED TO PARK HER CAR

easy. This time, the set made a better effort to start up and with the HV unit disconnected, was able to give a healthy spark for a moment or two. But then it would close down and the LED would flash.

This time, I decided to take the horizontal deflection panel (E) with me, plus the convergence board (D), the latter also carrying the vertical output IC. Back at the workshop, I carefully examined each board, cleaning and soldering dry joints as well as replacing any component that looked even slightly suspicious.

That done, I replaced the vertical output IC (IC1501, STV9379) and resoldered the convergence output ICs. I also thoroughly checked the protection circuits on the E board and checked the flyback transformer for shorted turns.

Having done all that, I was optimistic that everything would now be OK. However, I also took a new HV unit with me on this my third attempt to fix the set in-situ.

I cannot tell you how difficult it is to service a large TV in the middle of a carpark, out in the open. Unfortunately, despite being sure that these three boards were now OK and having installed the new HV unit, I still hadn't made any real progress. I did manage to check the main voltages but was then forced to abandon the whole exercise when another unit owner wanted to park her car.

Finally, I fronted up to the client and told him that it had to go to the workshop or nothing more could be done. Fortunately, he could see the sense in this and said he would arrange for it to be delivered.

When it arrived, I got stuck into it and found that the set was trying hard to come on but just wasn't making it. I then decided to unplug large chunks of circuitry until it stabilised itself.

This took some time and there wasn't much left connected when I finally disconnected the focus lead from the flyback transformer. That turned out to be where the problem lay and with everything else reconnected, the CRTs began at last to light up and the sound came on.

Now that I knew where the fault lay, I played around with the focus and G2 control assembly but soon came to the conclusion it was "shot". I then ordered and fitted a new one and the set behaved a lot better but it still wasn't completely fixed. In particular,


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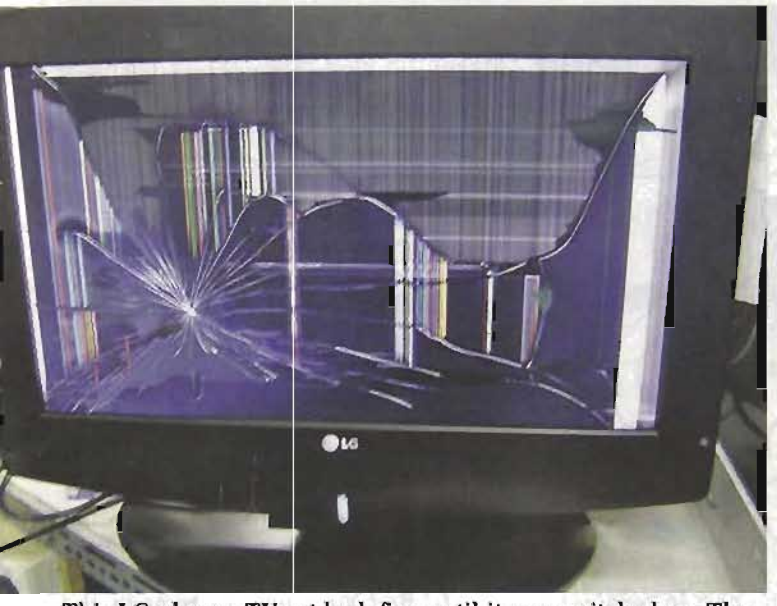

This LG plasma TV set look fine until it was switched on. The display had somehow been smashed internally, probably due to the set being knocked over.

This is what happens to a magnetron when the fan cooling isn't working effectively. The melted cooling fins are clearly visible.

the picture was very poor, particularly on the blue gun.

It took a long time before the penny finally dropped. It was the blue tube that was dragging down the focus voltage of the whole set and destroying the focus control and G2 assembly.

I removed the blue CRT socket and disassembled it completely. And once inside, the problem was self-evident. The focus spark gap assembly had become completely corroded, causing arcing and shorting everywhere inside the CRT socket (Part No. 1-251-179-21).

Ironically, the red and green CRT sockets were totally unaffected. The old HV unit was also faulty, as it was arcing from fine carbon "varicose veins".

I have now decided that the logistics are just too difficult in handling these huge sets – especially when all the electronic circuitry is just 80-100mm above the ground and access to the underneath is appalling. I doubt that I will try fixing any more of these monsters in the future – although hunger may force me to change my mind.

## LG plasma TV

Take a look at the photo at top left of this page. It shows an LG plasma set that looks fine when it is switched off but shows amazing colours when on. The display is smashed internally.

## Panasonic microwave

A Panasonic microwave oven came in unable to cook. The overworked and underpaid technician quickly diagnosed the magnetron as the culprit and fitted a new one.

Now all magnetrons look very similar and their part numbers are also very similar and often interchangeable. Essentially, magnetrons vary only in their power output and type of fastening.

Our bloke stuck this magnetron in and checked it for its ability to boil water in the specified time. Everything tested OK and the oven was returned to its owner.

About a month later, the oven was returned with the same complaint and our technician performed the rework. Sure enough it was the magnetron again but why? Eventually the penny dropped.

The replacement magnetron he had fitted was incorrect. The mounting screws are 90° out which meant that


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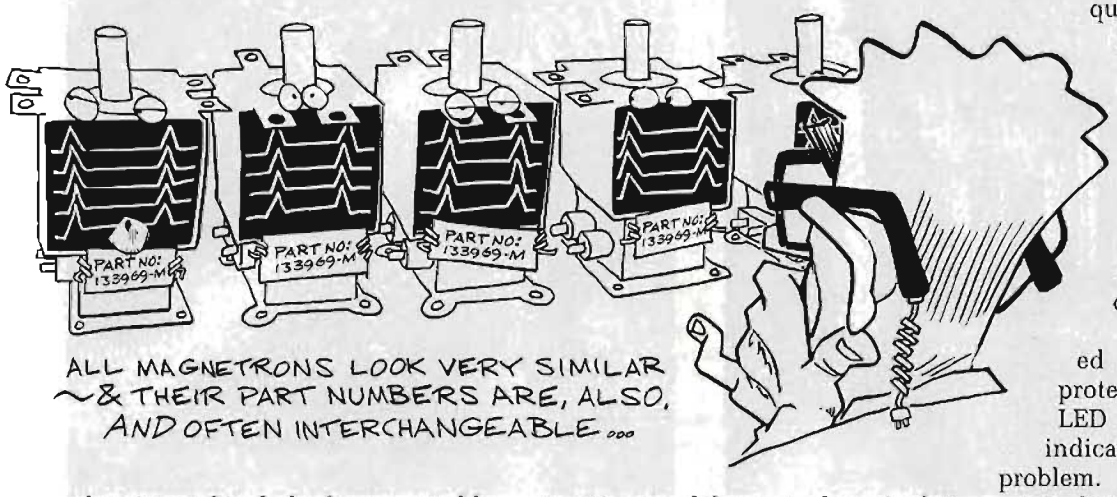
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PART NO: 133969-M
ALL MAGNETRONS LOOK VERY SIMILAR ~& THEIR PART NUMBERS ARE, ALSO, AND OFTEN INTERCHANGEABLE ...

when it was fitted, the fan was unable to blow onto the cooling fins of the magnetron. This in turn resulted in it overheating and melting – see photo.

## Sony HD TV sets

Although it's always been a problem, the number of jobs that now end prematurely for financial reasons is on the increase. Most service companies charge for the time taken to produce an estimate of the cost of repairs but unless you actually complete that repair, you cannot do better than a wild guess. This particularly applies if one fault masks another.

I had two separate cases recently involving the Sony AX-1 chassis. These sets are barely out of warranty and are 1080i HD CRT TVs with all the bells and whistles, and cost around $3000.

The first was a KV-HX32M31 and even a causal glance at all the AV plugs and sockets on the rear revealed large quantities of corrosion and rust. This set had spent a lot of its life close by the beach – in fact, if it had been any closer it would have been giving surfing lessons.

The insides of the set were just as bad, with every metal surface now coloured brown with rust.

When the set was switched on, it went straight into protection mode with the red LED flashing three times. This indicated a B+ overvoltage (OVP) problem.

My first step was to remove the deflection and main-power supply board (D). This showed extreme corrosion everywhere – even the resistors were rusting!

A few quick measurements soon revealed that R6512 (1Ω) – a feed resistor for the +135V rail – was open circuit. Replacing it made the error code change to four flashes which means "Vertical Deflection Stopped"


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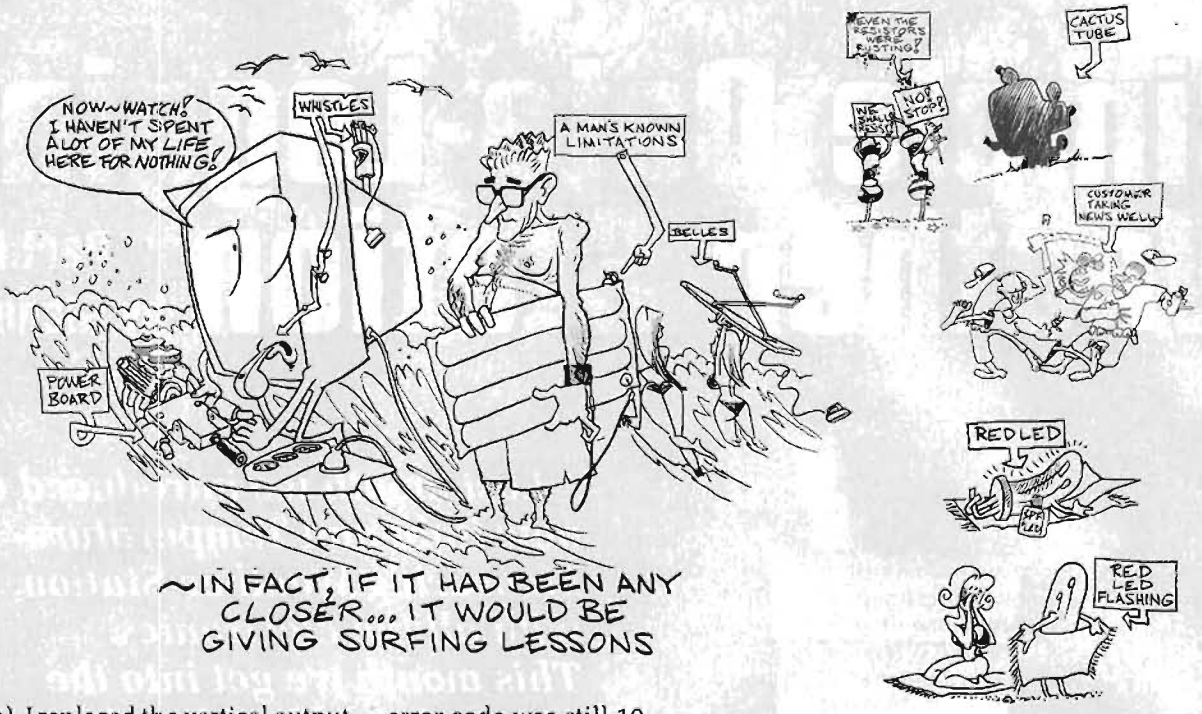

NOW~WATCH! I HAVEN'T SPENT A LOT OF MY LIFE HERE FOR NOTHING!
WHISTLES
A MAN'S KNOWN LIMITATIONS
BELLES
POWER BOARD
~IN FACT, IF IT HAD BEEN ANY CLOSER... IT WOULD BE GIVING SURFING LESSONS
EVEN THE RESISTORS WERE RUSTING?
NO? STOP?
CACTUS TUBE
CUSTOMER TAKING NEWS WELL
RED LED
RED LED FLASHING

(V-Stop). I replaced the vertical output IC (IC5101, STV9379A) but this made no difference.

By this stage, I had already decided that I would have to quote for a new board. It wasn't cheap but the client accepted the estimate and a new board dutifully arrived and was installed.

This time the set came on but it was arcing inside the picture tube which was down to air. I examined the tube very carefully but couldn't see any holes or cracks in the glass but it was definitely cactus. Unfortunately, a 76cm HD flat widescreen CRT costs as much as a new set so that was the end of the job.

To be fair, the customer took the news well but it all cost us a motza. Apart from all our wasted time, there was also the restocking fee for the board when it was returned to Sony, so we were well out of pocket.

Ironically, the second set, a KV-HR32M31, arrived not long after the new board had been returned.

Its fault was that it was giving an error 10 code which means "high-voltage stopped" (HV-PROT).

The deflection and power circuits for this set are similar to that of a computer monitor (which it can be), except that the picture tube is much bigger. I would have to say that it is one of the most complex sets I have ever had the misfortune to service.

I noticed that by jiggling the G2 adjustment on the flyback transformer, I could sometimes get a poor picture that could last from a few seconds to a few hours – even when the red LED error code was still 10.

As an experiment, I tried winding back the sealed HV Adjust pot (RV8002) but it made little difference to the symptoms even though it did vary the EHT, which was 31kV. The G2 voltage seemed to be the problem – it never rose above 100V. This was because it was being held down by a power transistor circuit (Q9014) on the CRT board (C) which is strapped across the G2 line via a 100kΩ resistor. This is called the "Power Mute Circuit" and I had never encountered it before. I assume that if the set develops an EHT fault, the microprocessor tries to reduce screen burn by removing the G2 voltage.

In this case, I felt fairly sure that the flyback transformer was the problem and quoted accordingly. Once again, this was a very expensive spare part but the client was happy to pay. Unfortunately, when it was ordered and installed, it didn't change a thing – the fault was still there.

This was turning out to be yet another financial disaster, just like the last set. In the end, I decided that the cost – in labour and materials – could still be very open ended and so I decided to abort the job and cut our losses.

Naturally, the owner was disappointed and I hate leaving it like this, especially as I am busting to know what is causing these faults. But as Dirty Harry used to say "a man's got to know his limitations".

## Out-of-focus Grundig

Because of its size and weight, I agreed to do a service call on a 2002 Grundig Lenaro 92 TV set (MFW92-6110/9 DVD using a CUC1937 chassis). This must have been one of the last Austrian-built Grundigs before BEKO took it over and it cost about $7500.

The complaint was that the focus was poor and then the set died. When I arrived, you couldn't help but admire the enormity of this huge 92cm CRT console television set. This model also included a built in DVD and flash-drive MP3 player, not to mention a 6-channel 140W Dolby AC3 amplifier.

This is all well and good but it meant removing a lot more stuff before I could access the chassis inside the cavernous TV cabinet – or should I say TV hall?

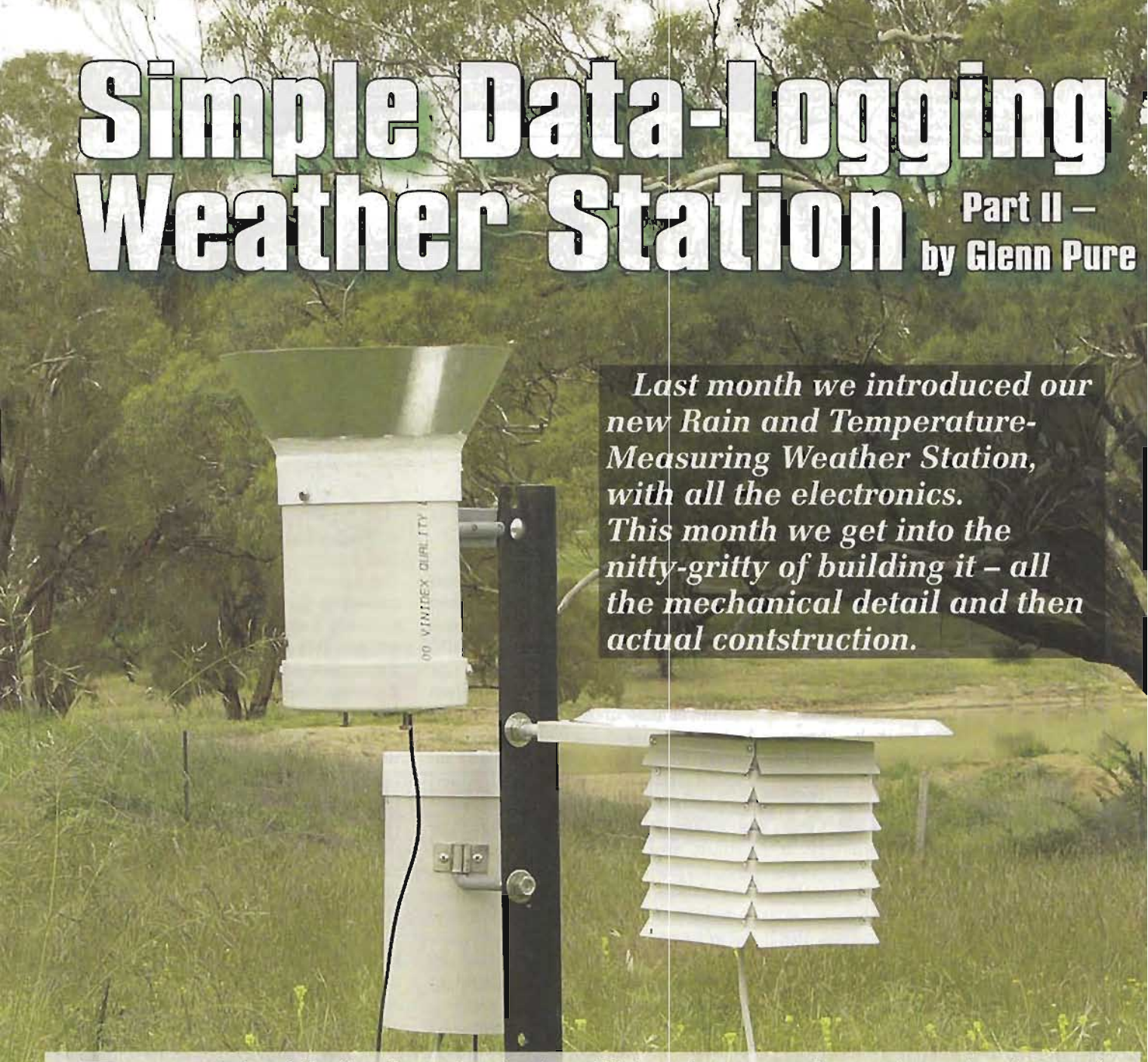
Anyway, I eventually managed to slide the chassis out to get access to the dynamic focus panel. However, before I could finally reach the components I was after, I had to remove a plastic support panel, with all its clips and silicone rubber.

The parts in question were two 1.5nF 6000V Wima capacitors in the focus accelerator. I replaced them with blue ceramic capacitors before tediously reassembling the whole thing.

This turned out to be a disaster because when I finally switched the set on, it was still out of focus. I then tried adjusting the focus control on the accelerator panel but it was already at its end stop. In the end, I had to realign the focus control on the CRT board before it was all back to normal. SC

# Simple Data-Logging Weather Station

## Part II – by Glenn Pure



*Last month we introduced our new Rain and Temperature-Measuring Weather Station, with all the electronics. This month we get into the nitty-gritty of building it – all the mechanical detail and then actual contstruction.*

**By now, we've hopefully whetted your appetite** with this simple design. Most of the mechanical detail here is "roll your own" but there is an alternative commercial rain sensor available if you don't have the time or inclination to make one. For those who do . . .

### Making the rain sensor

The rain sensor uses a tipping bucket mechanism, consisting of a rain collection funnel that feeds water into a pivoting bucket divided into two opposing halves. When one side of the bucket fills and tips, it empties itself, at the same time positioning the opposing side under the funnel outlet where it can fill, tip and repeat the cycle.

The tipping back and forth can be detected in various ways. Since power consumption was important for this project, a passive sensing mechanism was chosen. This involves momentarily closing a switch each time the bucket tips. As shown in the circuit diagram, the switch closure pulls the rain sensor line low (it is normally held high by a 220kΩ pull-up resistor).

To keep the design simple and maximise reliability, I used a magnetic reed switch that is mounted on a bracket next to the tipping bucket.

The switch is closed by a tiny rare-earth magnet (measuring only 3x2mm) that is mounted on the tipping bucket. As the bucket swings, the magnet moves past the reed switch, closing it for a brief moment. A similar mechanism is found in many commercial rain sensors and has the advantage that the reed switch is practically immune to moisture, corrosion, etc.

For its light weight and non-magnetic properties, the tipping bucket and its mount are made from 0.7mm thick aluminium sheet.

You may well have some of this in the junk box, from those utility boxes that come with both an aluminium lid and a plastic one.

The only problem with using this

The main funnel is glued using silicon sealant into a 100mm PVC pipe end-cap which has its end removed. Note the mesh leaf and insect trap on the bottom end.

The water then passes into the secondary funnel, mounted on a U-shaped bracket fixed to another (complete) PVC pipe end cap. You can see this end cap in the next photo.

Under the secondary funnel is the tipping bucket mechanism which fills with water and tips when it gets too heavy. A magnet on the tipper trips a reed switch to indicate one "fill".

sheeting is that it is work-hardened, making it difficult to bend and shape easily.

This can be fixed simply by heating, which will anneal the aluminium and make it much easier to shape. I used a blow torch for maybe 10 or 20 seconds, with the flame constantly moving over the piece. Do ***not*** heat it so that it starts to glow. If you don't have a blowtorch, try sitting the sheet on an electric stove (solid) hotplate for a minute or two.

However, before annealing the sheet, mark out and cut the bucket according to the plan shown. For accurate cutting, use a utility knife to score the sheet repeatedly, then bent it back and forth along the score line to snap it (a motion of only 10° or so each way is enough). Practice on a scrap piece – you will quickly get the idea.

Next, very lightly score a line along the centres of the drill holes. Continue this line across the whole width of the sheet as it is useful later when centring and mounting the divider between the two halves of the bucket.

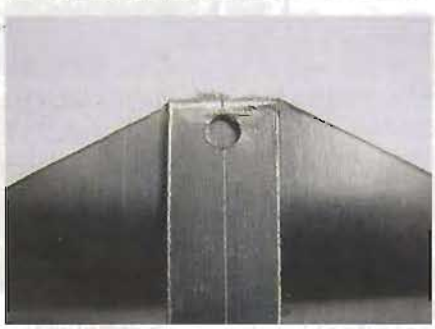
Drill the holes now as it is a lot easier before the bucket is bent into shape. The holes for the axle in the tipping bucket should be very slightly larger than the axle and located as marked on the template. It's important that the axle sits close (a millimetre or two) below the bottom of the main body of the bucket as this makes for more sensitive operation.

Now, anneal the sheet then proceed to bend it into shape. Start by bending the bucket supports (containing the axle holes) back down against the body of the bucket. Keep the bend sharp, for example by clamping along the bend line in a vyce.

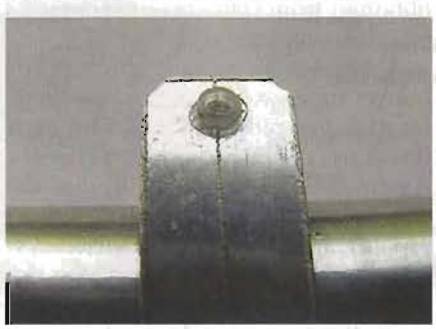
Next shape the main body of the bucket by bending it over a tube or rod about 25-30 mm in diameter. A broom handle works well, as does some 1-inch diameter PVC pipe. Make sure the result is symmetrical and even in shape, both lengthways and sideways. The aluminium should be quite soft and easy to re-shape if necessary.

Finally cut a divider to separate the two halves of the bucket. The width of the divider will depend on the diameter of the rod used to shape the bucket.

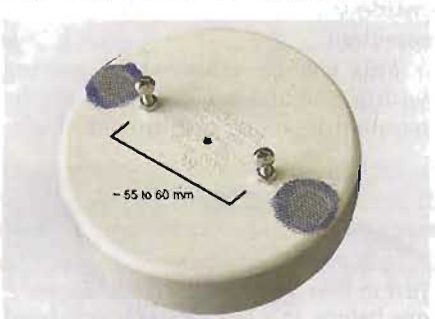
The divider is 'glued' into place using a small amount of silicone sealant or epoxy. It's a good idea to include narrow (3 mm wide) right angle flanges on the sides of the divider to help glue it in place (see template). Once the glue has set, smear a thin bead of silicone sealant along the edge of the divider, where it meets the inside of the bucket, to ensure water doesn't flow from one half of the bucket to the other. A 'cotton tip' from the medicine cupboard will do the trick. Minimise



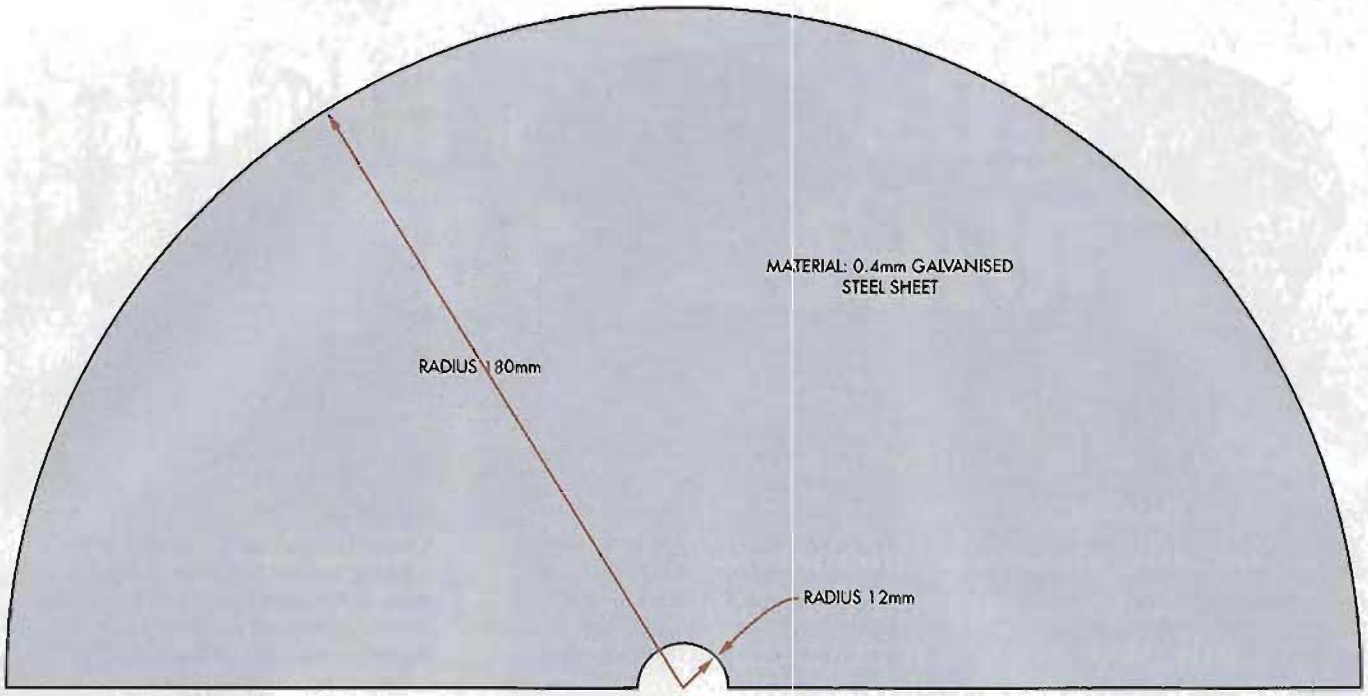
Here's the way the magnet is mounted on the tipping bucket – it (or in some cases they) is/are glued into this hole made in the side (top) of the tipping bucket.



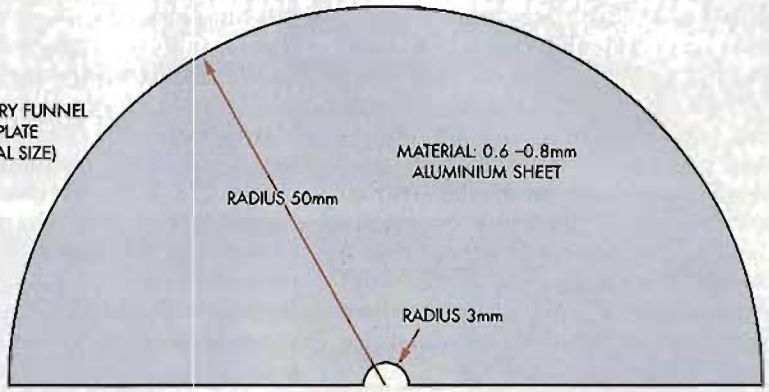
Another close-up of an important part: the plastic washer which stops the bucket mechanism fouling the mounting bracket. Without this readings may be erroneous.




Once the bucket has tipped and the water measured, it needs to escape. These mesh-covered holes in the pipe end-cap are for that purpose. Note the measurement for the two screw holes.




MAIN FUNNEL TEMPLATE (50% ACTUAL SIZE)




**These two templates will help you make your main (primary) and secondary funnels. The main funnel catches the rain, the secondary funnel directs it into the tipping mechanism. Note that the main funnel template needs to be blown up 200% when photocopying, otherwise it will be a tad too small! The overlap when you bend the funnel shapes should be about 8mm. Seal this overlap with silicone sealant.**

the amount of silicone applied, but apply it to both halves of the bucket to better balance the two sides.

The rare earth magnet can now be glued into the locator hole on the upper side of the tipping bucket.

One more thing is needed to finish the tipping bucket. When it is in operation, it appears to empty more efficiently and consistently if the inside surface of the bucket is water repellent.

This can be achieved by coating with a silicone car polish. Don't be tempted to smear a thin coat of silicone sealant as this tends to be sticky and collects fine particles over time, impeding the proper operation of the tipping bucket.

**Just in case you haven't come across one before, this is a glass-encapsulated magnetic reed switch of the type used in this project. Its contacts are normally open and close in a magnetic field. The most sensitive areas of a reed switch are towards each end.**

The tipping bucket pivots on a thin axle. For this, a short length of stainless steel wire (1.4 mm in diameter) was used, although galvanised steel wire would probably be fine. The diameter isn't critical. The wire was obtained from the whisk part of a $2 stainless steel egg whisk.

A bracket to mount the tipping bucket on its axle can now be made from another piece of aluminium sheet (don't use steel sheet as it is magnetic). Again, drill the holes in this for the axle before bending.

The exact dimensions of the bracket will depend on the width of the tipping bucket. Precision isn't necessary since washers or spacers should be used to keep the tipping bucket away from direct contact with the bracket, ensuring unimpeded tipping motion.

Such spacers (or washers) are also important to ensure minimum sideways play of the tipping bucket on the axle. Avoiding such play will keep the magnet on the bucket positioned a constant distance from the reed switch each time it swings past. A distance of about 3-4mm should be the target (face of magnet to centre axis of reed switch). Adjustment of the bracket to achieve the correct spacing is made by simply bending it.

If the magnet is too close, the force of attraction between it and the reed switch can be sufficient to cause the tipping bucket to lock in centre position. If the gap is too great, the reed switch simply won't close. The spacers can be cut from the end of the plastic ink tube of a ballpoint pen.

The reed switch is glued to the outside of the bracket that holds the tipping bucket. Be warned that the part of the reed switch that is most sensitive to the magnet is either end of the switch, not the middle of it, so

ensure the reed switch is mounted so the magnet swings past one end (see diagram). A separation of 3-4mm between the magnet and the reed switch is best.

Care is needed when soldering wires to the reed switch since it appears to partly melt at soldering temperature. Hence it is essential to use a good heatsink between the switch and the end of the wire being soldered (firmly gripping with a pair of needle nose pliers will achieve this).

Once soldered up, the switch and connections should be covered with sealant to waterproof them since the connecting wires on the switch are made from steel and will corrode over time if they get wet.

The tipping bucket is housed inside a length of 100mm diameter PVC 'sewer' pipe. A rain collection funnel is fitted to the top end of the pipe. The funnel was made from thin (0.4mm) galvanised steel sheet (see template).

After bending, it was held in shape with pop rivets then the join soldered up, although silicone sealant would be fine also. A piece of fine wire gauze was then bent and glued over the bottom end of the funnel. The gauze was scavenged from one of those gauze covers for frying pans that are used to stop the fat spattering. Two-part epoxy or silicone sealant would be fine to glue this in place.

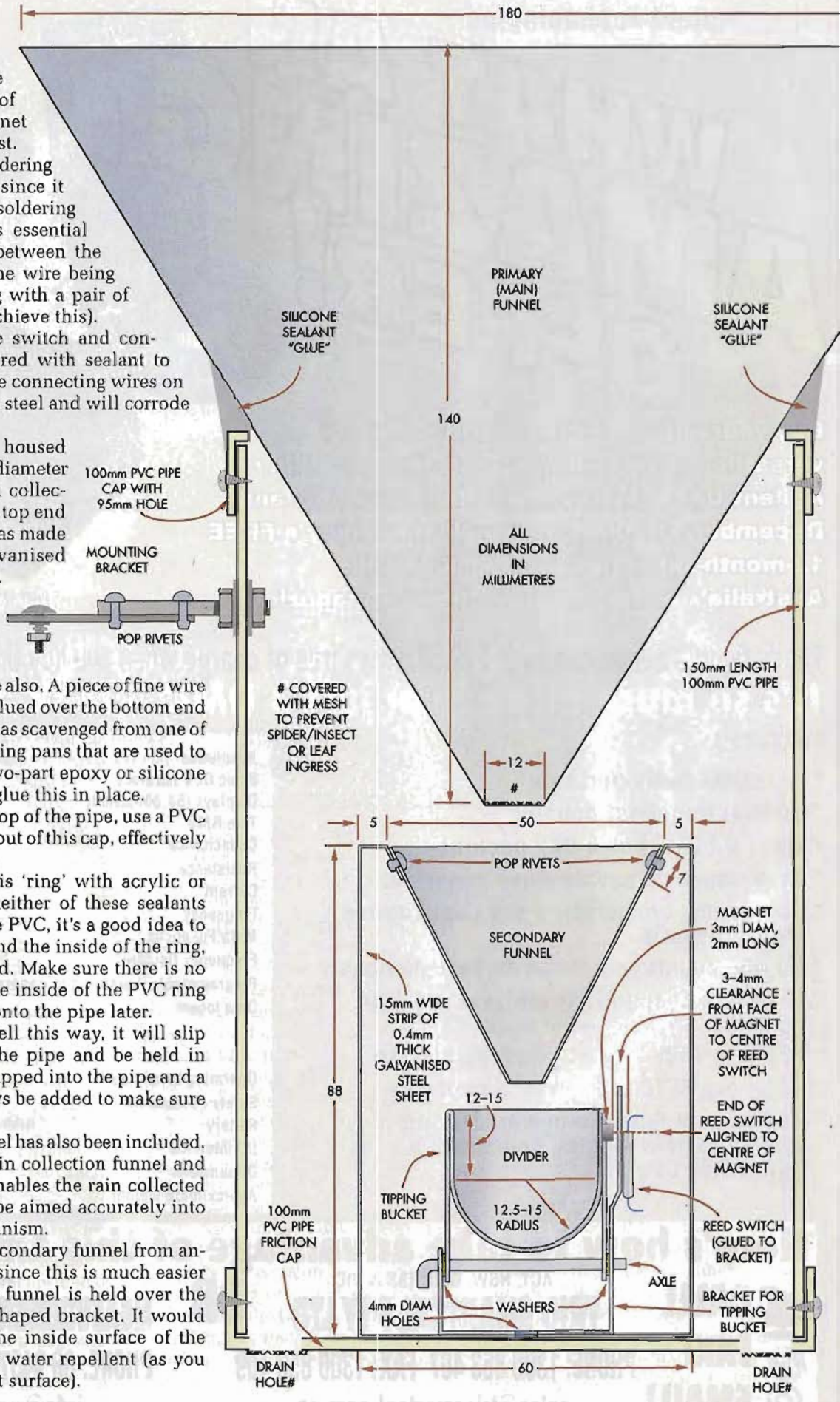
To fit the funnel to the top of the pipe, use a PVC pipe end cap. Cut the end out of this cap, effectively leaving only the sides of.

Fix the funnel into this 'ring' with acrylic or silicone sealant. Since neither of these sealants will stick very well to the PVC, it's a good idea to run a bead of epoxy around the inside of the ring, after the sealant has cured. Make sure there is no sealant or glue fouling the inside of the PVC ring otherwise it won't slide onto the pipe later.

By mounting the funnell this way, it will slip nicely over the end of the pipe and be held in place by gravity. A hole tapped into the pipe and a machine screw can always be added to make sure it doesn't move.

A small secondary funnel has also been included. This sits between the main collection funnel and the tipping bucket and enables the rain collected from the main funnel to be aimed accurately into the tipping bucket mechanism.

It is best to make the secondary funnel from annealed aluminium sheet since this is much easier to bend into shape. This funnel is held over the tipping bucket by a 'U' shaped bracket. It would be a good idea to coat the inside surface of the secondary funnel so it is water repellent (as you did for the tipping bucket surface).



The tipping bucket itself, along with the secondary funnel, is bolted onto another end cap which slips onto the bottom of the PVC pipe. The two are mounted together to keep them in alignment.

Two 20 mm long screws (with locking nuts) have also been tapped into the end cap and sit underneath each half of the tipping bucket. They are used to adjust the amount the bucket will hold before it tips. Brass or stainless steel machine screws (M4) and nuts should be used throughout for corrosion resistance.

There are two larger holes opposite one another near the edge of the end cap. The holes should be about 12-15mm in diameter and are the exit points for the water from the tipping bucket when it empties. Make sure the outside of these holes is also covered with fine wire gauze (glued in place) so that insects or other debris can't get inside the sensor and foul the mechanism.

## Calibration

Once the sensor is assembled, calibration can then be done. Make sure the end cap is placed on a level surface before starting. Calibration is done by slowly dripping water into the primary or secondary funnel and measuring how much it takes before the bucket tips.

Do this 10 or 20 times and average the results. Aim for about 5ml each time, using the adjustment screws under each side of the bucket to fine-tune the tipping point. Ensure the same amount of water is needed no matter which direction the bucket is tipping.

To convert the amount needed to cause the bucket to tip into millimetres of rain, first measure the diameter of the top of the primary funnel in centimetres then calculate the area of this opening. (To find the area, divide the diameter by two to get the radius, square this value then multiply by $\pi$ (3.1416)).

The area in square centimetres will be the number of millilitres of rain the funnel will collect for every 10mm of rainfall. You will get a value of about 250ml for an 180mm diameter funnel, or about 25ml per mm of rainfall. If it takes 5ml to fill and tip the bucket each time, that is 0.2mm of rainfall for each bucket tip.

## Electronics housing

We showed the electronics "box" in part 1 last month. However, it needs to be housed so it is protected from the elements (and nosy cows, etc!).

A "case" can be made from the same 100mm PVC pipe and a friction-fit pipe end, as were used to make the rain gauge.

Note that in this case I elected to use only a top cover, leaving the bottom open to the elements "just in case" something leaked and it decided to fill with water.

The box is not secured to the pipe; rather it hangs from a simple metal hanger mounted to the top pipe cover and the back of the jiffy case. The cabling simply drops out of the bottom of the case.

All cabling must be secured to the star picket or other mounting poles – a cable dangling in the breeze is too much of a temptation to curious livestock (especially cattle!).

## Mounting the sensors and controller

Most of the hard work is done. The main job left to do is to assemble and mount the bits and pieces. Since this is designed for use in remote locations, I assumed that a quick and simple way to mount the sensors and weather- proof the electronics was needed.

A star picket commonly used for fencing was used. These have convenient pre-drilled holes though which brackets made from bolts and steel

## Parts list (louvred housing)

All sheet metal used in 0.4mm thick galvanised steel (0.6mm thick aluminium is preferable for the louvres themselves but is harder to obtain.)

**Sheet metal**

1 170 x 170mm (for top cover)
1 150 x 150mm (for top)
5 400 x 25mm (for louvres)
4 110 x 20mm (for corner supports – you should use galvanised steel for strength to make these even if you do make the louvres from aluminium sheet)

**Other**

30 small pop rivets (to fix louvres to corner supports)
3 4 x 30mm machine screws and nuts
3 20 mm long spacers to suit 4mm machine screws
1 mounting bar made from aluminium channel (12 x 12mm), approx 150mm long (for mounting the housing)
2 6-8mm long pop rivets (for mounting bar)
1 50 x 8mm bolt, head cut off, with nut and two washers to suit (for mounting bar)

## Parts list (rain gauge)

1 360mm square sheet metal (main funnel and bucket parts, U-shaped bracket)
1 100mm diam semicircle
1 150mm length 100mm PVC pipe with friction caps
1 magnetic reed switch
1 3mm diam x 2mm rare earth magnet
Various screws, pop rivets and scraps of metal

# Making the temperature sensor housing

For accurate readings, the location of the temperature sensor is important. It must be placed so that it is not affected by radiant heat from the sun or other direct heat sources. It should also not get wet as evaporation would cool a wet sensor – yet there should be free air movement around the sensor to enable it to equilibrate with the current air temperature.

To achieve the right conditions, professional weather stations usually include a louvred housing that is typically mounted a fixed height above ground level (1.25 metres is apparently the international standard). The housing shades the sensor and stops it getting wet while allowing free air flow.

If the housing itself gets hot, it can heat air that passes through it and cause an incorrect reading at the sensor. So the housing should be painted white so as to minimise the absorption of radiated heat and generally designed to reduce the chance that the housing itself will create a localised heating or cooling of the sensor different to the current air temperature.

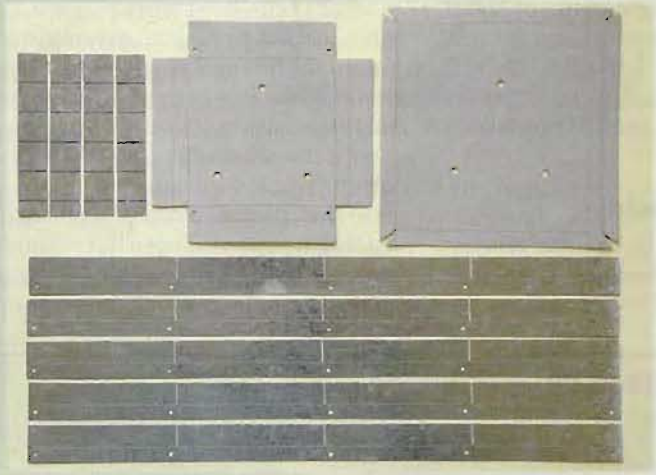
A louvred housing can be made relatively easily from thin sheet metal. Aluminium sheet about 0.6mm thick is ideal for ease of handling, low thermal mass and weight but may be hard to obtain. If this isn't available, use 0.4mm galvanised steel sheeting.

The housing design consists of a top, a top cover over this to improve resistance to radiant heat from overhead, four vertical corner supports and five louvres made from bent sheet metal which fix directly to the corner supports. The easiest way to assemble the housing is with pop-rivets. A piece of aluminium channel is also pop-riveted or bolted on to the top cover for mounting of the whole assembly.

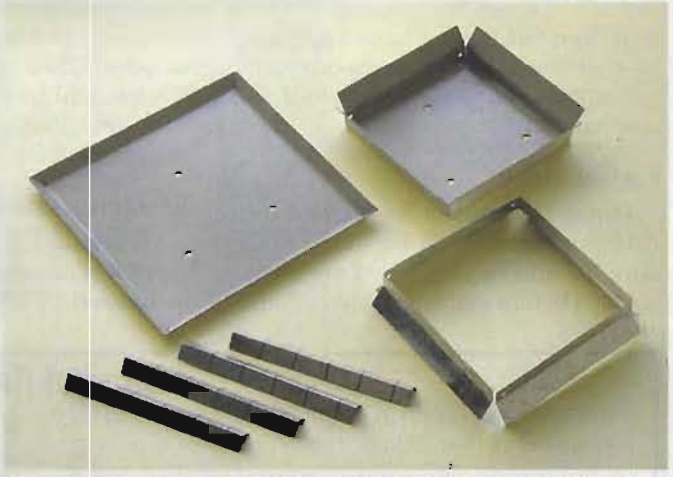
Commence construction by cutting out all the sheet metal parts as shown on the template. Don't bend any of the parts yet. It's a good idea to drill the holes that will be needed for assembly now since this is easier to do on flat (unbent) sheet). Start with the top and top cover. First, tape them together in accurate alignment and drill three holes (4mm diameter) as shown on the template – this will ensure that the holes in the top cover align with those in the top when you come to screw the top cover on. Four holes for pop-rivets can also be drilled in the top.

Pop-rivet holes can also be drilled in the louvres. Don't drill any holes in the corner supports though. Now bend the top and top cover into shape as well as bending the corner supports and louvres as marked in the template.

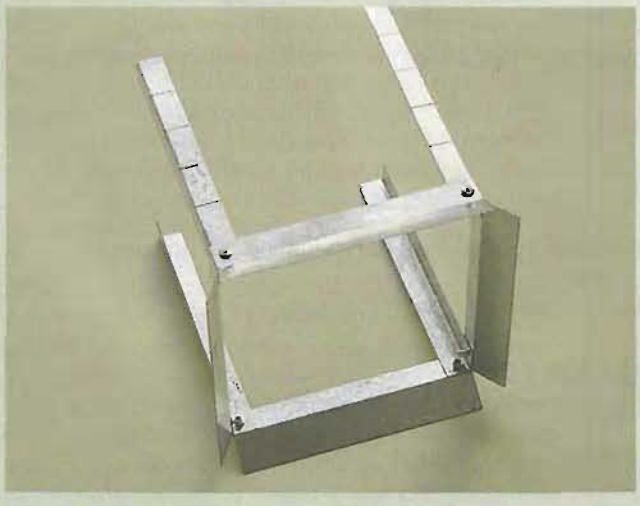
Mark lines at 20mm intervals along the



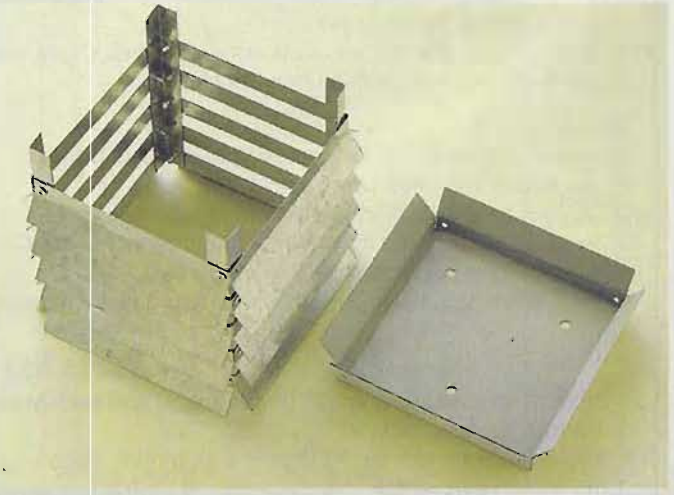
**It's not a template but this photo can be used as a cutting and drilling guide for your temperature sensor housing.**



**Here are the components for one side of the housing – the largest piece is the top cover, the four pieces below the side guides.**



**And here is that first louvre fixed to the four side supports. Once you have achieved this, the rest is easy!**



**A few minutes later and all louvres are fitted, now ready for the top cover to be fixed in place.**

corner supports (these will be used to align the louvres). The last line marked will be only 10mm from the end of the corner support and is where the first (bottom-most) louvre will be mounted. Drill and pop-rivet the bottom louvre to the corner supports so its top edge aligns with the 10mm line (see photo).

The easiest way to drill the corner supports is to clamp a short length of scrap timber (19 x 42mm cross section) to the work bench so it protrudes from the bench. Hold the corner support with a large bulldog clip while the louvre is placed over it and the hole is drilled (see photo).

The next louvre up can now be pop-riveted into place, aligning its top edge with the next mark 20mm along the corner support. Fix the remaining louvres into place. When all the louvres are fixed, the top can be pop-riveted on. The top should slide nicely over the upper ends of the corner supports if you have measured, cut and bent accurately.

The housing is now almost finished. It's now time to make the mounting bar, which is made from a piece of aluminium channel. I used 12mm channel since this makes it easier to fit a bolt to the other end (an 8mm diameter bolt will fit easily in the channel).

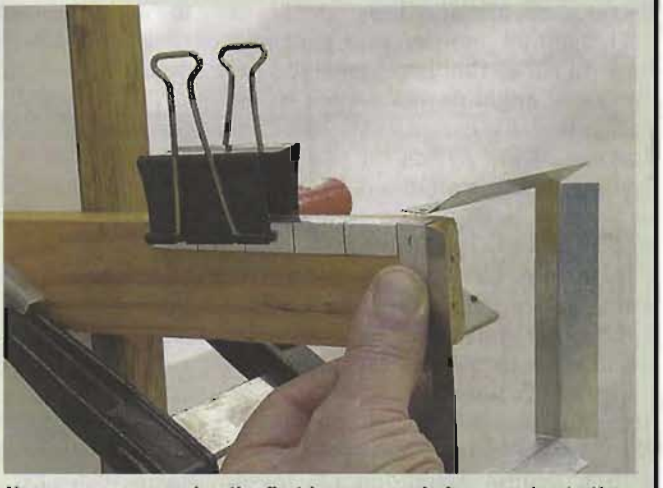
The easiest way to hold the bolt in place is to put it in a vice and crush the top edges of the channel over the bolt shaft (see photo). Two part epoxy will ensure it stays in place.

Next rivet the mounting bar to the top cover after first cutting away a portion of the channel so the mounting bar will sit flat on the top cover (the prototype louvred housing shown in the photos in part 1 had the mounting bar fixed under the top cover but this is clumsy so don't try it) . Now fix the top cover in place with machine screws and spacers

Finally the housing should be painted white to minimise absorption of radiant heat. A can of fast drying spray paint is the easiest way to do this. Remember that several light coats are better than one heavy coat.

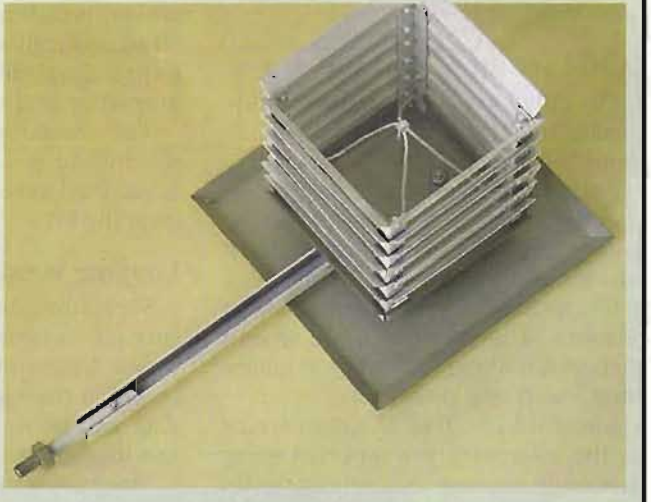
The temperature sensor itself is mounted on short lengths of wire that are suspended from the corner supports of the louvred housing (simply bend them around the top of the corner supports between the top and the first louvre). The sensor should be mounted in about the centre of the louvred housing and can be held in place with a twist tie or short length of wire. Make sure it can't drop out when left unattended for a lengthy period.

**Drilling holes in small, thin bits of metal is not only tricky, it can be dangerous if you don't properly clamp and support the work.**



**Here we are preparing the first louvre, ready for securing to the corner support with a pop rivet.**

**The mounting bar is made from a piece of U-shaped (channel) aluminium with an 8mm bolt crushed in position then secured with two-part epoxy. This is then secured to the (inner) top cover with pop rivets. The outer top cover, which helps prevent the housing from heating up and giving false readings, is mounted 12mm above the inner top cover by means of 12mm threaded Nylon standoffs so there is no heat conduction from one part to the other.**



**An upside-down finished view of the housing. The four stiff wires inside the housing support the temperature sensor itself.**

**Left: the controller box inside its PVC pipe case. It hangs free on brackets fixed as shown above. The pipe mounting bolt is flexible to allow the pipe to be moved at will.**

strips can be mounted. The photos illustrate how to make these up.

The mount for the rain gauge is constructed so that it can be tilted on two axes, enabling the sensor to be levelled when installed. Specifically, the base of the sensor, on which the tipping bucket is mounted, should be set so it is level otherwise accuracy will be degraded.

By the way, I haven't done a check to see how accurate the rain gauge is but commercial units of this type typically are accurate to within a few percent.

The utility box containing the electronics is also fitted inside a length of PVC sewer pipe. An end cap fitted with a simple metal bracket (bent from a piece of sheet metal) is used to 'hang' the utility box inside the pipe (see photo).

## Initial set up

The only job to do is to perform the clock correction if accuracy better than about five seconds a day is needed.

First, start the weather station by inserting three AA batteries in the battery clip. The temperature or rain sensors don't need to be connected. You will need an accurate means to measure 24 hours to within a second or so. A handheld GPS or good quartz wrist watch will do the job.

Alternatively, find a time service on the internet – use one that gives a seconds reading and automatically increments this (try www.timeanddate.com).

First, reset the controller using the reset button. With the case open, press the clock correction switch momentarily and note the exact time it was pressed.

The LED will come on as soon as the switch is closed and stay on for 4 seconds to indicate that the clock correction process has successfully started. Note that the clock correction switch will be disabled 30 minutes after a reset (assuming the controller has been programmed with a 30 minute logging frequency).

At the same time the next day, about 20 seconds before 24 hours has elapsed, the LED will come on. At exactly 24 hours, press the clock correction switch again. The LED will turn off and the correction value will be stored.

If you forget to press the switch, while the LED will turn off after about 40 seconds, no correction value will be recorded and the controller will resume normal operation.

The correction value is stored in the PIC in non-volatile memory, so is retained even if power is removed from the PIC.

## Logging weather data

Set up the rain and temperature sensors, power up the weather station, and reset it. Make a note of the time and date at which the reset occurred. The first data will be recorded 30 minutes (or one logging frequency) after the reset.

The rain and temperature sensors can be plugged in at any time, although, obviously, nothing will be recorded until they are.

Even though the temperature sensor is a programmable digital device, the software in the weather station enables it to be plugged in and unplugged even when the weather station is operating. If the rain sensor is left unplugged or faulty, zero values will be recorded for temperature.

There is nothing else to do, except come back in a month – or a year – and download the data.

## Downloading the data

Downloading is also straight forward. Instructions are printed on the front label of the weather station. Freeware data logging software is used to receive the data (see below) on your computer or laptop. This software will write the data to any file you nominate.

Data is transmitted in text form as comma-separated values that can easily be imported into spreadsheets. A 'header' is transmitted first, listing the total number of data points recorded since the last reset.

The weather station does not record the time directly. You will need to calculate the time of each data record based on the time the weather station was reset (or powered up) and the logging frequency. Don't forget that the first data set isn't recorded until one logging period after the weather station is started.

Some basic error detection is also built into the software. When each data record is written, the value 255 (decimal) is also written to all four bytes of the next record.

During a data dump, if the weather station software encounters these values, it will transmit the following text string "BREAK" then "NULL" on the next line.

Since data only up to the last valid record are normally transmitted, such a BREAK will never be seen during a normal dump operation. It will occur if there was a power down and power up, or an internal reboot of the weather station while it was operating.

A reboot will occur if the software detects some abnormal conditions during operation, such as a suspicious looking interrupt. It can also occur if the internal record counter becomes corrupted, although this in unlikely.

An entire dump of the weather station's data can also be performed. This will show a BREAK where data finished recording following the most

recent reset. BREAKs may also be seen further into the data record from some earlier resets (only those that weren't overwritten since the last reset).

Performing a full data dump of the entire EEPROM contents is easy. Simply do a reset on the weather station just before doing a data dump.

A sample spreadsheet is attached showing weather data recorded from 17 January 2007 to 4 March, in my backyard in Canberra. Some plots of the data are also included, including a very heavy rain event where about 50mm fell in 30 minutes. The rain gauge is able to handle both heavy and light rainfall events, although I would expect problems with extremely heavy rain or hail.

## If you need to change the logging frequency...

The firmware is nominally written for a 30-minute logging frequency, meaning rain and temperature will be recorded every 30 minutes. The logging frequency can be changed by modifying the firmware, recompiling this and reprogramming the resultant hex file into the PIC.

The software for the PIC contains the following defined constants near the start:

```
LOG_FREQ    EQU D'6'     ; Frequency (minutes) with which data is logged
HRS24       EQU D'240'   ; = (No of minutes in 24 hours)/LOG_FREQ
```

Changing these will change the logging frequency. The above example shows a logging frequency of 6 minutes. Setting LOG_FREQ to 30 (decimal) and HRS24 to 48 (decimal) will give a 30 minute logging frequency and a normal 24 hour clock.

Logging frequencies down to one minute are possible but the HRS24 value can only be a maximum of 255. The only thing HRS24 affects is the frequency with which clock error correction occurs (including the initial setting of the clock error).

So if LOG_FREQ is set to 1 and HRS24 set to 255, the PIC will apply the clock correction value every LOG_FREQ x HRS24 minutes (ie 1 x 255 minutes).

Similarly, performing an initial clock calibration will complete 255 minutes after it is started, not 24 hours later.

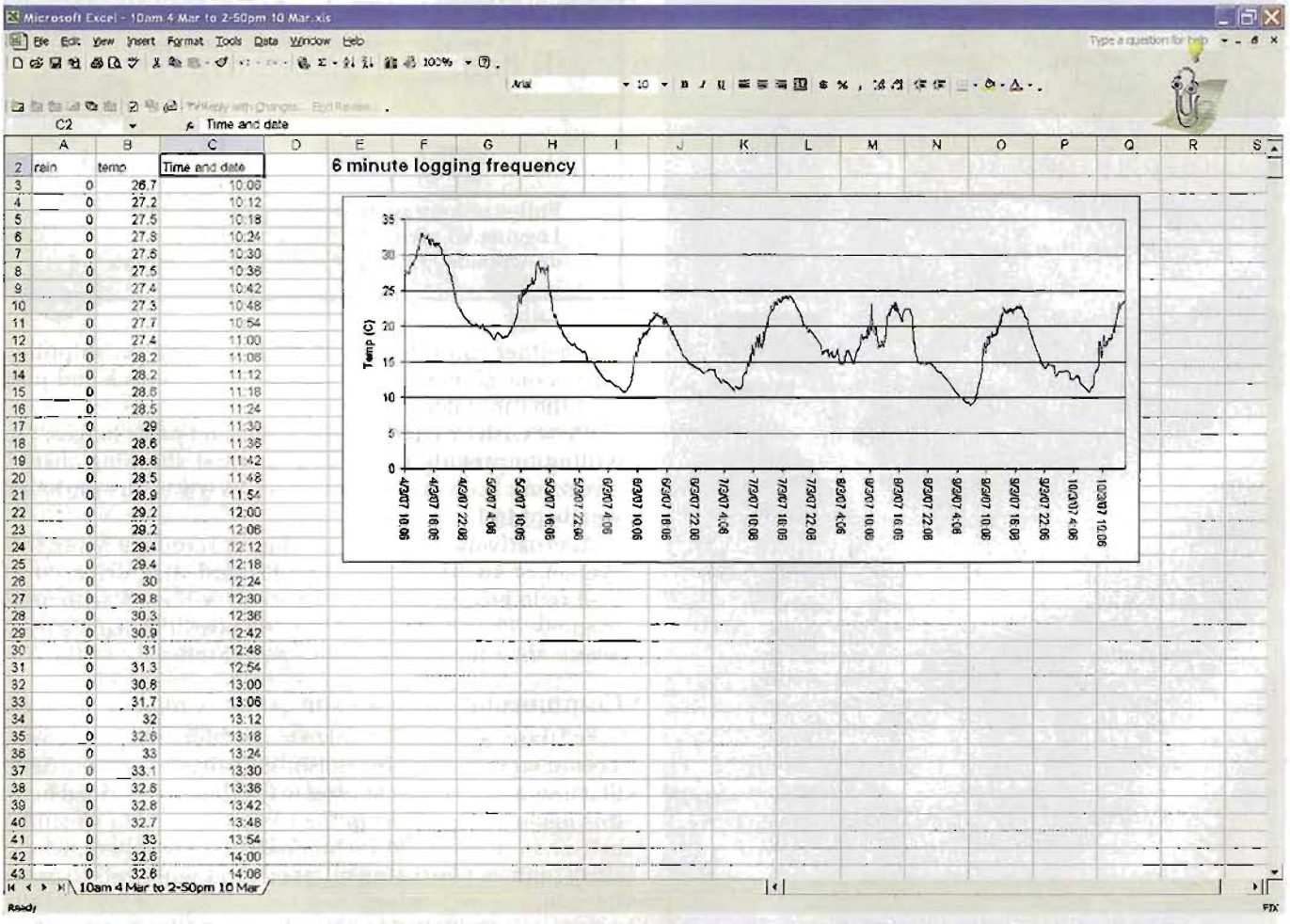
## Where to obtain the special parts and software

The data logging software is available from www.eltima.com/products. Download the freeware "RS232 data logger".

The 3x2mm rare earth magnet is available from Oatley Electronics in Sydney (www.oatleyelectronics.com) for 25 cents each plus $7 pack and post).

Similar 3 x 1mm magnets are also available from www.frenergy/com.au (12 cents each; $5.50 pack and post) – you will need two of these stacked to get a magnet with the same power as a 3 x 2 mm magnet.

I contacted both of these suppliers




An Excel spreadsheet from the Author's installation outside Canberra. Because the data from the Weather Station is virtually "universal" in format, can be used in a wide range of applications.

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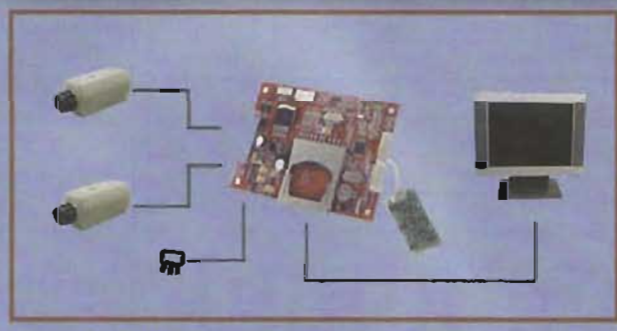

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**Full-size front panel artwork for the Data Logging Weather Station. It can also be downloaded from www.siliconchip.com.au**

and neither can offer any further discount on shipping. This is one case where it costs far more to pack and post than the (tiny) items are worth.

If you wish to avoid the high pack and post charges, I'm willing to provide them for a nominal shipping charge. Check my web page for details (www.evans-pure.net/weather.htm).

Alternatively, you may be able to scrounge a suitable magnet or two from, say, an old hard disk drive. Most reed switches are quite sensitive and will work with most magnets. The advantage of the "rare earth" magnets used here is their incredible size-to-power ratio.

## Commercial rain sensor

For those who don't want to make their own rain sensor, a commercially available sensor is available for about $200 that uses a similar mechanism to the sensor described here. It is made by Peet Bros in the US and is sold in Australia by Sphere Innovative Technologies (www.sphere.net.au/site/products.php?cat=wm_acc). You will need to order the "Rain gauge – wired".

I haven't tested it myself but have investigated its specifications and am confident it will work. SC

# PRODUCT SHOWCASE

## New V2 UltraWAP multi-mode WiFi Access Point

Freenet Antennas has released Version 2 of the highly successful UltraWAP multi-mode WiFi access point (AP).

The UltraWAP is like a swiss-army knife of WiFi units. It has five modes allowing it to behave as:

(1) an AP – the centre of a Wireless network,
(2) a Station (client if you like) where it connects to an AP,
(3) Bridge – acting like a LAN switch in the sky,
(4) Wireless Distribution System (WDS) – acting simultaneously in AP and Bridge modes, or finally
(5) Universal Repeater – acting simultaneously in AP and Station modes.

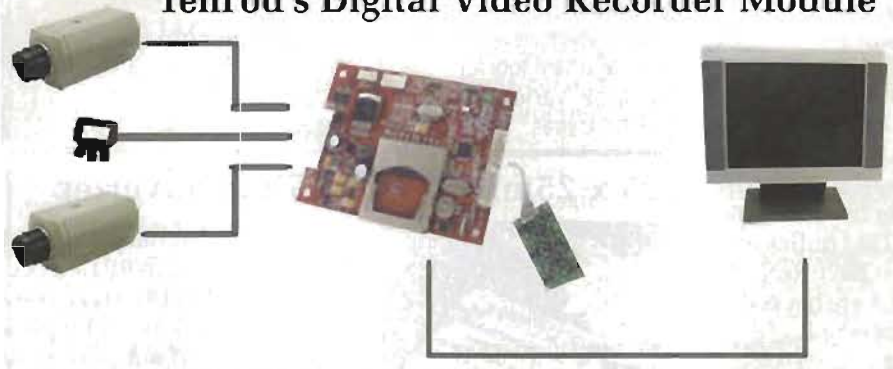
The Version 2 (V2) UltraWAP sees a new radio chip introduced with much improved receive performance. Freenet Antennas has measured a clear 5dB improvement in receive performance compared to the V1 unit. That translates to a 78% increase in receive range!

It also means more distant signals can be detected and connected to. Because of the extra receive sensitivity, a pair of these units can make a 20km point-to-point link when coupled with 19dBi grid antennas and antenna coax – without violating the ACMA 36dBm radiated power limits. (Refer to last month's SILICON CHIP).

The UltraWAP comes in a range of transmit power options, from 60mW to 200mW making it the most versatile WiFi unit on the market today in Australia. At prices starting from $99, it is also the best value.

Contact:
**Freenet Antennas**
3 Barker Place, Bicton, WA 6157
**Tel:** (08) 6262 3333 **Fax:** (08) 9319 3275
Website: www.freenet-antennas.com

## Tenrod's Digital Video Recorder Module



Do you need to record movements or events and not have to wait for them to happen? In video or in still images? Perhaps store them for later retrieval and playback?

Tenrod have introduced an easy-to-operate, automatic and low-cost video recorder (in module form) – which will do all of this and more.

With its motion detect feature, the DVR81XX module can record movements or events (in video or still images) of the target area and store them on an SD card. A 1GB SD Card can store up to 15,000 seconds of video or 17,000 still images. When there is no activity, there is no recording, saving storage space.

At the same time, the module can provide a live output to a TV monitor from 2 input channels of cameras. It has picture-in-picture feature as well as on-screen-display.

It also has an alarm output which can alert an operator, trigger an alarm or activate other functions.

The module is without enclosure, to provide versatility for installing into tight spaces or into enclosures of the user's choice. It requires only a single DC (9V to 12V) power source to operate the whole system.

The recorder would be ideal for continuous monitoring of a place or processes that need to be analysed for research or for development or troubleshooting. The memory storage and playback facility will facilitate the data retrieval for this analysis. It can be used with infrared cameras for night-time operation.

Kits complete with cameras and cables are available to make a convenient start to putting up a system. Small 4-inch TFT colour LCD screens are also available for use as a small portable monitor in conjunction with the module.

Contact:
**Tenrod Australia Pty Ltd**
1/24 Vore St, Silverwater NSW 2128
**Tel:** (02) 9748 0655 **Fax:** (02) 9748 0258
Website: www.tenrod.com.au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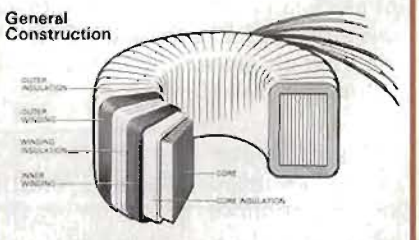


**Manufactured in Australia**
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9/40 Leighton Pl. HORNSBY 2077
Ph (02) 9476-5854 Fax (02) 9476-3231

## Clock Radio with Docking Station

Most people are creatures of habit, leaving their clock radios (and other radios!) on one station. Maybe it's because most clock radios are so fidgety to change. But sometimes the programs on your favourite station are not what you want to listen to. Wouldn't it be nice to have an alternative without lots of fiddling?

Jaycar Electronics have a neat solution to this problem with this very advanced Clock Radio. Actually, they describe it as a Docking Station with AM/FM Digital Alarm Clock. That's because it is not only an advanced AM/FM radio with a host of alarm functions – and 10 AM /20 FM preset stations – it will also play back music from a USB "stick" and/or an SD/MMC card. You can even use it to transfer files between USB and SD/MMC.

What's more, you can tailor the sound response to the way you like it, just like the newer hifi systems. Settings are flat, pop, classic, rock, jazz and X-bass.

Like most clock radios, it has a snooze function. It also has dual alarms (which you can set to wake up to your choice of source – buzzer, radio, USB or SD/MMC) but unlike most clock radios, it has a weekend function which turns the alarm off on Saturday and Sunday. Settings are backed up with two AA cells (it's normally mains powered).

The output power is more than adequate – 1.5W x 2 and it has a headphone output as well as RCA outputs.

I have to confess that setting up took a bit longer (!) than the average clock radio but once done, it was a joy to use.

With a recommended retail price of $99.00, it's certainly not as cheap as the average clock radio these days but it does a whole lot more and is worth every cent. It's available from all Jaycar Electronics stores* and resellers (Cat GE-4064).

Contact:
**Jaycar Electronics (all stores)**
100 Silverwater Rd, Silverwater NSW 2128
Ph: (02) 9741 8555 Fax: (02) 9741 8500
Website: www.jaycar.com.au

* Jaycar have recently announced the relocation of two of its Sydney area stores to larger premises – Bondi Junction store is now at cnr Birrell and Bronte Roads (ph 9369 3899) and Campbelltown store is now at 1/50 Queen Street (4620 7155).

## New Test & Print Kit now available

Testing and tagging of portable electrical appliances can be very labour intensive. Wavecom Instruments have released two new testers which make the testing and tagging and the record keeping associated with it much easier.

The first has a memory built into it. It can store 5000 test items. Download the tests to be done today – or this week – to the memory in the tester, do the tests and upload the results back to the main database at your leisure. The kit includes a printer so tags are printed on site after the completion of the test. Multiple tests per item can be stored for consecutive tests.

The second new tester will be ideal if you don't need the memory function but just want to test & print. The system comes complete in a plug-in-and-start-testing case. Labels printed from tester can be customised to user needs. User names, site names and retest frequency are changed on the fly and printed on the robust label within two seconds.

All tests, including load, leakage and RCD tests, have results logged and recorded for uploading to the WinPATS MX software. WinPATS MX provides the user with a comprehensive asset management tool for a large variety of OH&S issues.

Contact:
**Wavecom Instruments**
257A Grange Road, Findon, SA 5023
Ph: (08) 8243 3500 Fax: (08) 8243 3501
Website: www.wavecom.com.au

## 25 x 25mm 15W DC/DC Converter

The revolutionary RECOM RP15-xxxxSA and RP15-xxxx-SAW series DC/DC converters are just 25 x 25mm and have a height of only 10mm, delivering a power density of 38W/in³ (2.3W/cm³). That's half the size of the industry standard.

An efficiency of up to 87% allows these new galvanically isolated converters to have an operating temperature range of -40°C to +68°C at full load without the need for any external cooling fans. However, the full load upper temperature limit can be extended further to 73°C with the optional heatsinking pack.

By means of simple external filter, EN-55022 Class B limits can be met (an appropriate common mode choke is also available from RECOM), otherwise no external components are required for normal operation. A trim pin allows the outputs to be adjusted by 10% and a remote pin can be used to power-down or sequence the output.

Contact:
**Cutter Electronics**
5 Highgate Way, Rowville, Vic 3178
Ph: (03) 9753 9911 Fax: (03) 9753 9455
Website: www.cutter.com.au

# Trio Smartcal's new under-$1000 "Atten" Colour Scopes!

Aimed at the enthusiast and economy-conscious buyers, the ADS7000 series range of low-cost Digital Oscilloscopes from ATTEN, while low in price, are value-packed with features such as sample rates of up to 1GS/s per channel and the inclusion of USB on all models.

PC communications software is also included in the price as is the USB cable to link to your PC.

Features include peak detect for glitch capture, average mode for noise reduction, pulse width trigger, video trigger with individual line select and a full suite of automatic waveform measurements.

Equivalent time sampling increases the resolution on faster repetitive signals too. Measurement cursors are also standard as is an intelligent AUTOSET function that enables the user to select positive or negative edges, an individual waveform cycle and series of cycles.

Window mode is more than just a basic magnification or zoom function as found on many other low cost oscilloscopes.

On the ADS7000 series when the window mode is selected it actually adjusts the timebase, increases the sample rate and adjusts the trigger delay to bring the selected area on screen with the optimal capture settings. This ensures that the waveform feature of interest is displayed at the highest possible resolution.

Backed by a 3-year warranty and in-country support, these new scopes will be a welcome addition to many enthusiasts' test benches – and with Christmas only four months away, will make the ideal present, even for yourself.

Prices start at $895 (+GST) (or $984.50!) for a 25MHz, 250MS/s, 2-channel model. At the other end of the scale, the flagship 200MHz model has 1GS/s per channel, USB device port (for PC connect) and USB host for memory stick, and costs just $1,995 +GST. Monochrome models are also available from just $795 +GST.

Contact:
**Trio Smartcal**
3 Byfield St, North Ryde NSW 2113
**Ph:** (02) 9889 3534 **Fax:** 1300 853 409
Website: **www.triosmartcal.com.au**


## Like to Phidget ? Phidgets

Phidgets are an easy to use set of building blocks for low cost sensing and control from your PC. Using the Universal Serial Bus (USB) as the basis for all Phidgets, the complexity is managed behind an easy to use and robust Application Programming Interface ( API ). Applications can be developed quickly in Visual Basic, VBA ( Microsoft Access and Excel), Labview, Java, Delphi , C and C++.

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***For Programers***
Wrap Phidget Libraries with your own Propriety software.
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There are a number of open source projects to get involved in.
Reach out into the world and make things happen.

***For Researchers***
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Phidgets are easy to program and use. No knowledge of hardware, microprocessors, USB, communication protocols, is needed. An imagination is recommended however.

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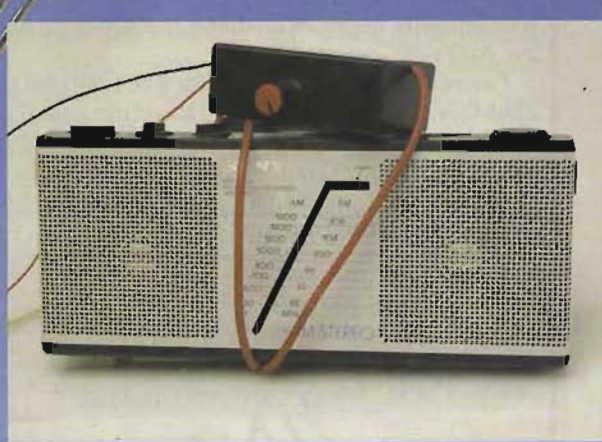
# LOOP ANTENNA AND AMPLIFIER

## for long-distance AM radio reception

Design by Branko Justic*
Words by Ross Tester

- Listen in to AM radio stations you only dreamed existed!
- Separate close stations
- Suits upper AM broadcast band
- Small enough for flats & home units



* Oatley Electronics

Once upon a time, listening to long-distant radio signals (whether on the broadcast or shortwave bands or even the amateur bands) was a popular hobby.

Hours upon hours were spent, listening for that elusive station . . . the ability to bring very weak stations "out of the mud" was the ultimate thrill.

In the 21st century (and at the risk of earning the ire of die-hard shortwave listeners!) those days have all but gone.

Today, there is little interest in the big, high-performance communications receivers of last century. A lot of gear came out of WWII, perhaps modified but there was an enormous amount of commercial receiver equipment on the market as well, reflecting the popularity of "listening".

Who can forget (if you were around 50 years ago!), the Marconis, Hallicrafters or Gelosos, the Nationals, Eddystones, Collinses or the build-it-yourself Heathkits?

Speaking of build-it-yourself, the late Ian Pogson described two mighty "Deltahet" Wadley-Loop communications receivers in (the also late!) "Electronics Australia" during the 1960s and 70s.

Later on came the Frogs (Yaesu's famous FRG-7) and many more. Have I missed your favourite? Sorry!

Those who still indulge in the art of "listening" are these days just as likely to use WinRadio in/on their PCs – which in many ways outperforms even the best of the communications receivers of yore.

In fact, the vast majority of receivers today have little more than the AM and FM broadcast bands.

## The aerial

There are three things which make a receiver "good". Two are fixed (at the whim of the designer or manufacturer).

First is the receiver's sensitivity, which is its ability to resolve very weak stations.

Second is the receiver's selectivity, which is its ability to separate stations whose transmit frequencies are very close. Note that NO receiver, on its own, can separate stations which are on the same frequency.

However, the third factor, which can often help a receiver distinguish between stations on adjacent frequencies (and even sometimes the same frequency) is the aerial or antenna.

Even though the terms are virtually interchangeable these days, no self-respecting old-timer would ever call his aerial an antenna. Antennas were those small flimsy things designed to pick up TV!

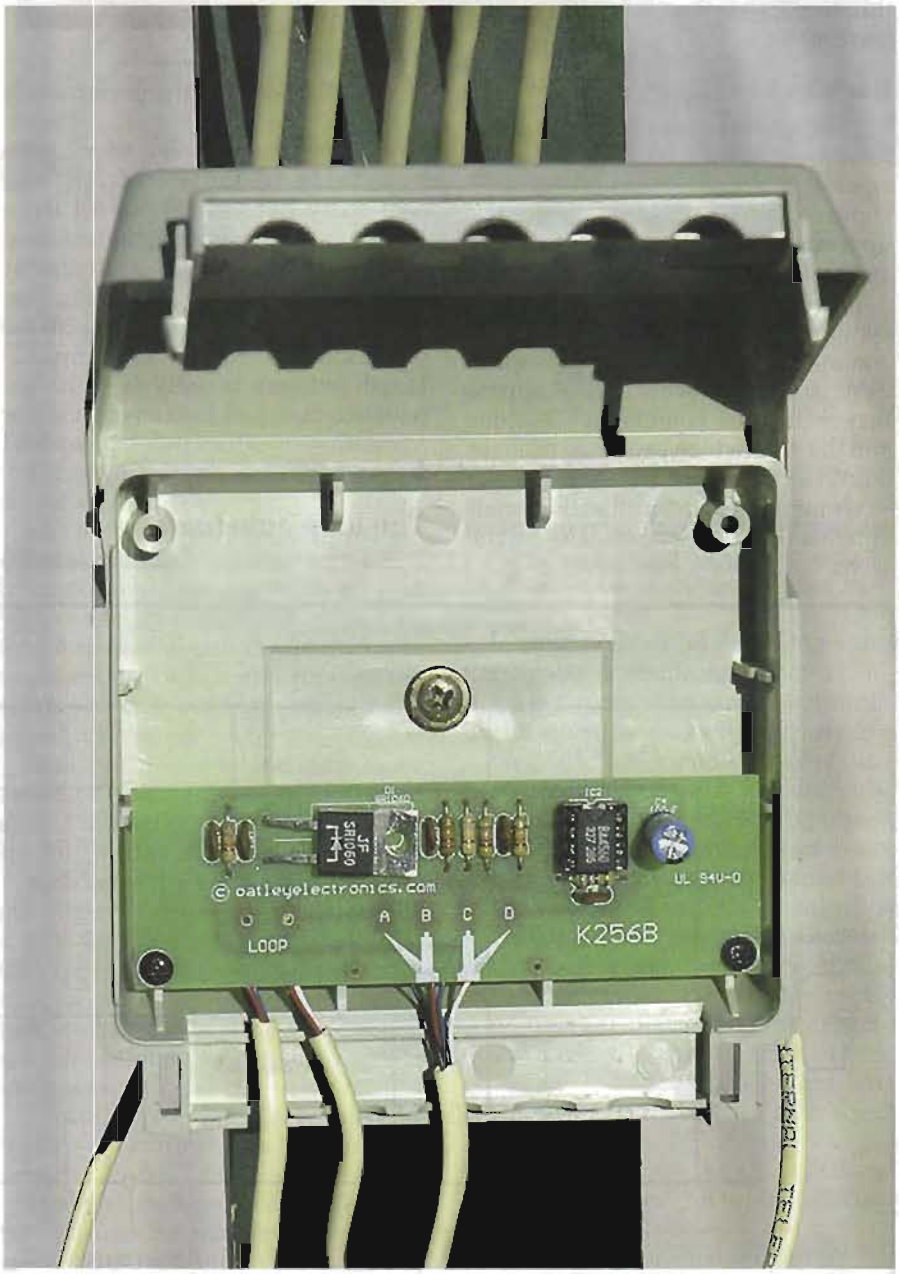
Unless you have made an in-depth study of aerial/antenna theory, to most people, many (most?) electronics hobbyists included, it's a black art.

Sure, everyone knows aerials/antennas are the "inductor" part of a tuned circuit which, depending on the antenna length, resonates at a particular frequency, according to the formula

$$\frac{1}{2\pi\sqrt{LC}}$$

where L is the inductance in Henries and C is the capacitance in Farads.

Wanted frequencies (ie, the station you want to listen to) can pass virtually unhindered but (at least theoretically) all other frequencies are rejected.




**Here's the top PC board mounted inside one of the low-cost Oatley weatherproof cases. The two cables entering left are for the loop antenna above (you can just see the loops behind the case lid). All four wires in this cable are soldered to the underside of the board together. The cable entering in the middle is the downlink – this cable has all four wires individually soldered to the underside of the PC board .**

If you make the frequency of the tuned circuit variable, then you have a means of tuning over a specific band of frequencies.

Well, at least that's the way it's supposed to work.

Old timers will tell you they used to use another aerial formula: "as long and as high as possible". You'd see many a length of wire stretched on poles "down the backyard" – or further.

But not everyone these days has the room (or the neighbours!) to allow this to happen. You need something smaller!

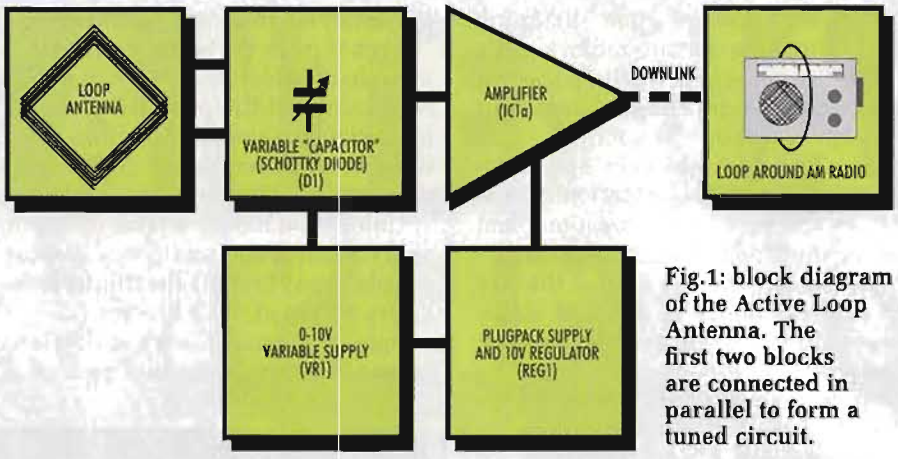



**Fig.1: block diagram of the Active Loop Antenna. The first two blocks are connected in parallel to form a tuned circuit.**

## Back to the future

This project is specifically intended for those who want to listen to distant, weak or interference-prone AM radio stations, particularly those in the upper portion of the band (eg, 1000-1600kHz).

This tends to be where the weaker stations are located – most country commercial AM stations are about 2kW; some are even less. Compare that with city commercial stations and the ABC which can be up to about 50kW!

We mentioned before that the aerial/antenna (OK, let's standardise on the word "antenna") can make a great deal of difference to the performance of a receiver.

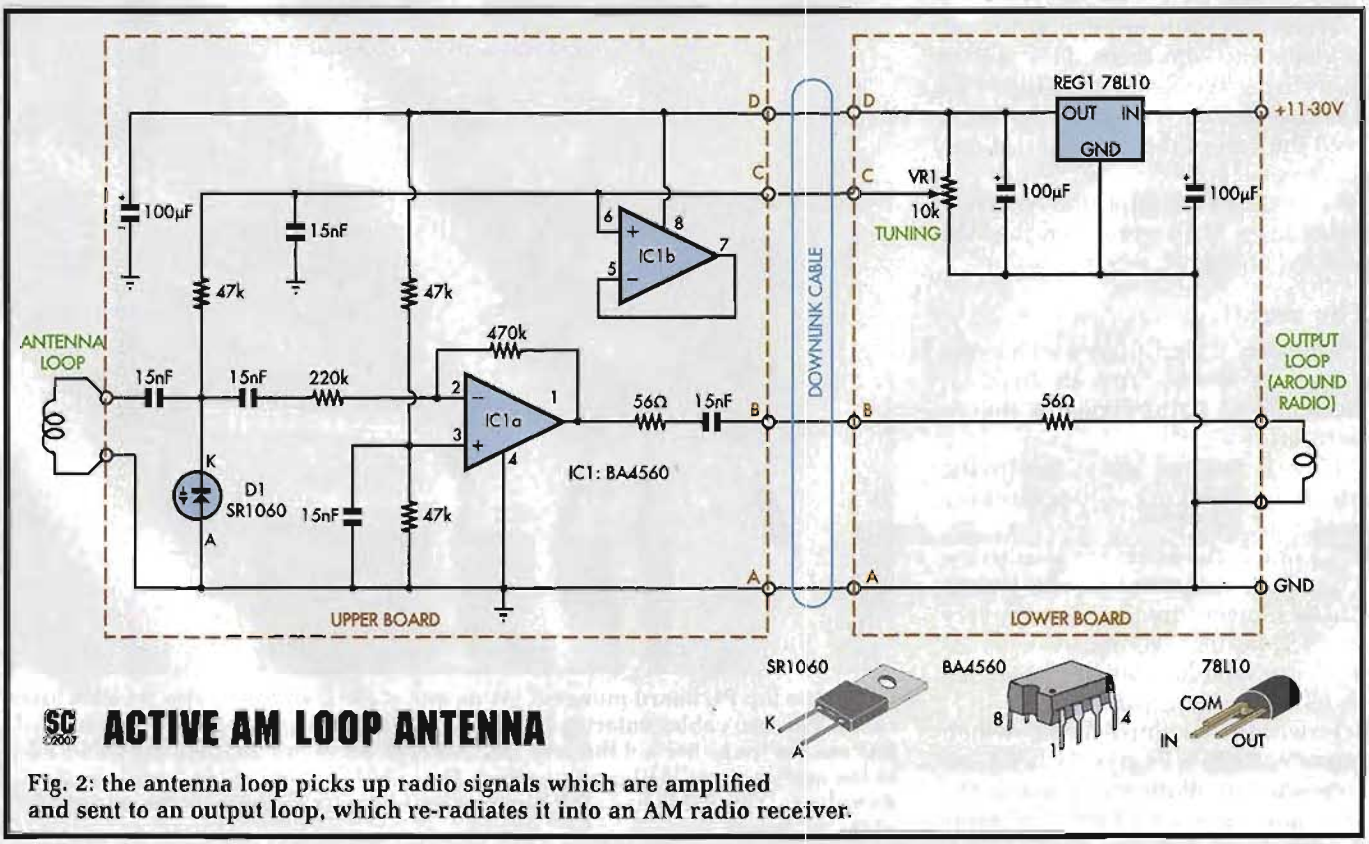
Modern receivers are often quite reasonable in the selectivity and sensitivity department, so all that's left for us to play with is the antenna. Even if the receiver has provision for an external antenna and earth, you might be quite disappointed with the performance because the random-length antenna is unlikely to be impedance-matched to the receiver nor resonating anywhere near the required frequencies.

## The loop antenna

A far better approach is to use the one we've gone for here – the loop antenna with an inbuilt amplifier. Moreover, the loop antenna exhibits reasonably good directivity – if you're trying to pick up a distant station and another station is swamping it, you can rotate the loop to "null out" the unwanted one.

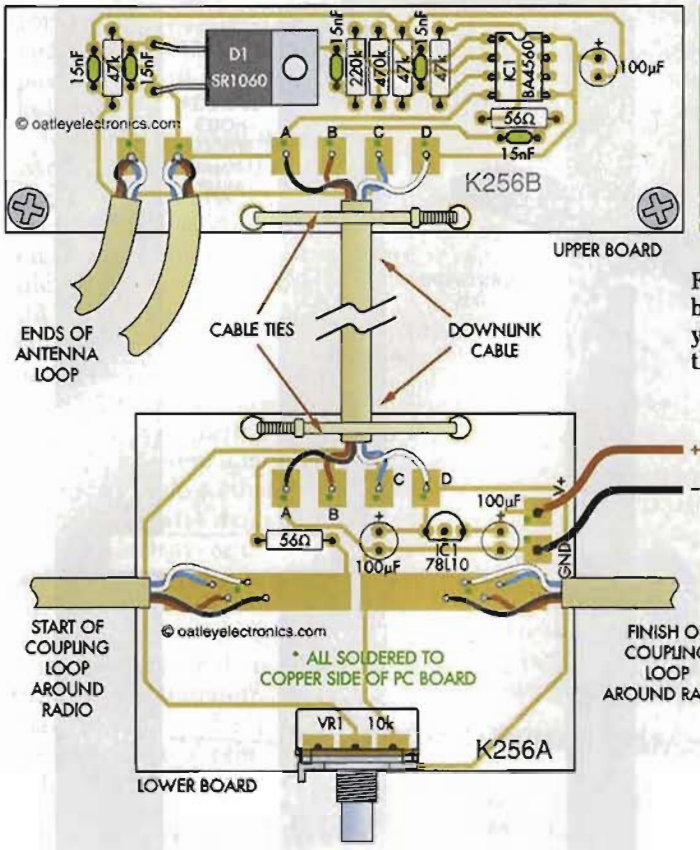
Coupling the loop antenna to the receiver is made simple because no physical connection is required. A second, single-turn loop couples the signal into the radio's inbuilt ferrite rod antenna.

The distance between the loop antenna and the receiver can usually be as much as you require – up to several




**ACTIVE AM LOOP ANTENNA**

**Fig. 2: the antenna loop picks up radio signals which are amplified and sent to an output loop, which re-radiates it into an AM radio receiver.**



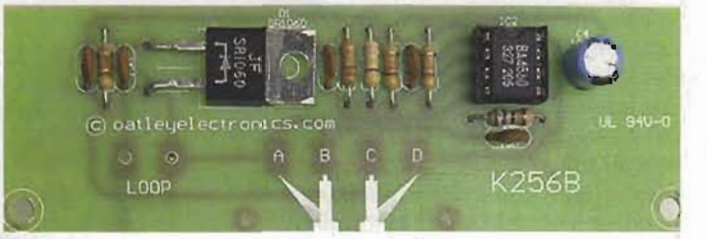




**Fig.3 (left): component overlays for the top and bottom PC boards, with their same-size photos alongside. The reason you cannot see any connecting wires to these PC boards is that they are all soldered underneath, to the copper side.**

tens of metres, in fact.

We should point out now that this project will NOT work on any AM radio which does not have an inbuilt ferrite rod antenna – this is the only way the received signal is coupled to the radio.

Incidentally, if you have a radio without a ferrite rod antenna but with antenna and earth connections, we described a somewhat similar loop antenna, designed to plug in to such connectors, in our March 2005 issue.

## How it works

First, look at the block diagram (Fig.1). It shows the operation of the loop antenna.

Countless electromagnetic waves passing through the wire loops – generated by anything from lightning to electric motors to radio and television stations – induce tiny electric currents at those frequencies.

The tuned circuit, consisting of the X-frame-mounted coil loops in parallel with a variable capacitance (we'll explain how this is achieved in a moment), effectively filters out almost all of these currents, except for the ones which correspond to its resonant frequency.

The resulting narrow band of signals is then fed into an amplifier, based on IC1a.

The amplified signals are then fed down to another coil, this one designed to wrap around the AM receiver. This loop re-radiates the signal so that the ferrite rod aerial coil inside the radio can receive it again and process the signal just as it would any other radio signal it receives.

What we are doing, therefore, is essentially "preconditioning" the signal so that the radio itself doesn't have to try hard to extract the wanted signal.

Remember those three things we mentioned earlier which determine a receiver's performance? Well, this circuit not only boosts the signal level, making the receiver more sensitive to weak signals, it also adds another stage of filtering, making the receiver more selective.

Therefore, performance must be better – and in fact can be markedly better!

To keep interference to a minimum, the X-frame loop antenna should be mounted outside the home, well away from motors, switches, etc.

## Making the tuned circuit variable

As you probably know, you can make a tuned circuit's basic frequency variable by varying either the inductance or capacitance (remember that formula above?).

In general, it's a lot easier to adjust the capacitance, although many multi-band radio receivers do change coils (inductance) when switching bands.

We could use a small variable tuning capacitor but these are not only hard to get, they're also getting rather expensive. The miniature ones commonly sold these days are incredibly fiddly to use and not at all conducive to tracking down weak radio signals!

But there is another way to obtain a variable "capacitor". Many semiconductors exhibit a change in capacitance when the voltage across them is changed. Varicap diodes are one such device and we could have used one of these.

However, we use the same characteristics, with an SR1060 Schottky diode.

At 0V, this diode has a capacitance of about 1000pF. At 10V, it's about 300pF. While this gives a 3.3:1 range of capacitance, when plugged into the formula above, this achieves a frequency range of only 1.83:1.

Therefore, we can only achieve a range of, say, 900kHz to 1600kHz. Fortunately, that's where most of the low-power distant stations lie in the band. If you want to extend the overall range, an extra turn or two on the coil or some more capacitance in parallel with the Schottky diode will do the trick.

It's something you can experiment with – you won't do any harm!

## Back to the circuit . . .

The supply voltage for this project can be quite wide – from about 11-30V DC. A nominal 12V plugpack, for example, will usually give about 16-18V unloaded and would be fine.

This voltage is regulated to 10V by REG1, a 78L10. The 10V rail supplies the amplifier IC directly and is also fed to a 10kΩ potentiometer (VR1) whose wiper is connected to the Schottky diode (D1) via a 47kΩ resistor.

At the top of its travel, the wiper will have the full 10V connected to the Schottky diode (equalling 300pF) while at the bottom, it will of course be near enough to 0V (1000pF).

The antenna coil is coupled into the Schottky diode via a 15nF capacitor. This stops the DC voltage which is being applied to the Schottky diode effectively being shorted to ground via the quite low resistance of the antenna coil.

Similarly, the output from the tuned circuit is coupled to the input of op amp IC1a by another 15nF capacitor so it cannot introduce DC into the amplifier circuit.

Finally, we should point out that only one of the two opamps in the BA4560 package is used. The other has one input connected to the positive supply and its other input to its output to ensure that it doesn't become unstable.

## Construction

There are three parts to the project – the "X"-shaped timber antenna support which houses the turns of telephone cable forming the antenna and two PC boards.

On one board we have the terminations for the loop antenna along with the amplifier section, while the second board has the power supply and connections for the loop to place around the AM radio receiver. Between the two boards is the downlink wiring.

Start by making your timber "X" frame, using the diagrams of Fig.4 for a guide. You can use just about any scrap timber that you can find (but we wouldn't use Pyneboard or other composites if the antenna is to be erected out in the weather. Any timber used should have generous coatings of paint applied to weatherproof it).

And don't forget to drill all the holes for the wire before you glue and screw the sections together – it's a lot easier to drill flat timber!

Wind the five turns of coil through the holes, starting with an outside hole closest to where the top PC board will be mounted – leave yourself about 200mm or so of cable to work with past the position where the PC board

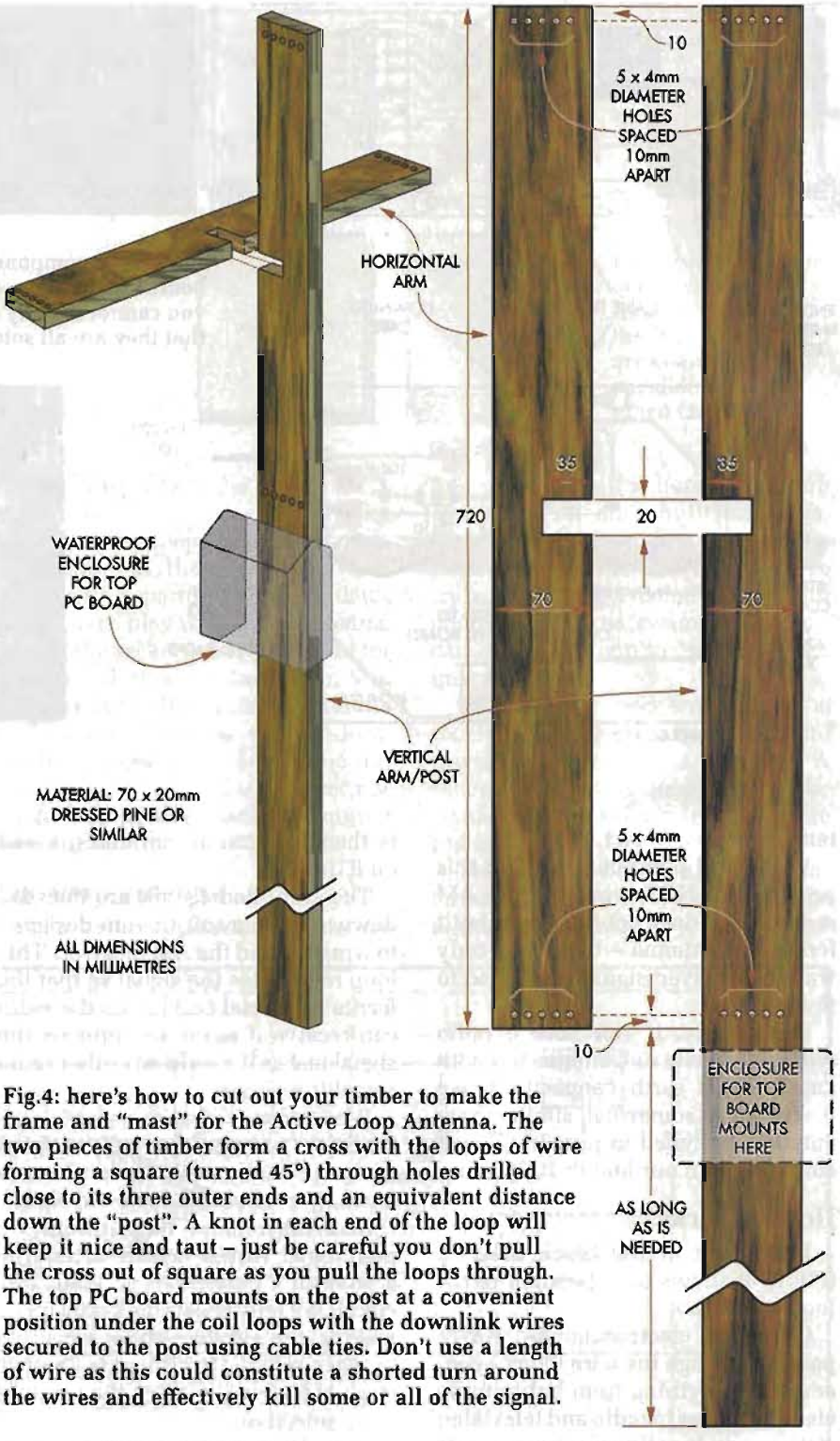



**Fig.4: here's how to cut out your timber to make the frame and "mast" for the Active Loop Antenna. The two pieces of timber form a cross with the loops of wire forming a square (turned 45°) through holes drilled close to its three outer ends and an equivalent distance down the "post". A knot in each end of the loop will keep it nice and taut – just be careful you don't pull the cross out of square as you pull the loops through. The top PC board mounts on the post at a convenient position under the coil loops with the downlink wires secured to the post using cable ties. Don't use a length of wire as this could constitute a shorted turn around the wires and effectively kill some or all of the signal.**

goes. Tie a single-loop knot in the cable as it passes through the first hole

Continue to pass the wire through the other three outside holes, then the next across and so on until the coil is complete. As you go, keep the turns of the coil nice and taut but not so taut as to pull the timber out of the "X" shape.

When completed, tie a single-loop knot in the last hole so that it keeps the wire loops taut. Again, leave yourself 200mm or so of cable underneath where the PC board will mount and then cut the remainder off. Hang onto that: you'll need it shortly for the downlink!

## Parts List – Active Loop Antenna

1 PC board, 31 x 94mm, coded OE-K256A
1 PC board, 58 x 48mm, code OE-K256B
1 Weatherproof plastic box (eg Oatley HB4)
1 30 x 54 x 83mm plastic box
1 8-pin IC socket

**Semiconductors**
1 BA4560 dual op amp (IC1)
1 78L10 voltage regulator (REG1)
1 SR1060 Schottky diode (D1)

**Capacitors**
3 100µF 16V electrolytic
5 15nF disc ceramic (code 15n or 153 or .015µF)

**Resistors** (0.25W 5%)
1 470kΩ (code yellow purple yellow gold)
1 220kΩ (code red red yellow gold)
3 47kΩ (code yellow purple orange gold)
2 56Ω (code green blue black gold)
1 10kΩ linear potentiometer (and knob to suit).

**Miscellaneous** (not included in Oatley Electronics kit)
Timber, screws and mounting hardware as required
40m of 4-wire telephone cable or equivalent

## PC board construction

It doesn't matter which board you start with – both are quite simple and should only take half an hour or so to complete.

On the loop antenna board, the only polarised components are the amplifier IC, the electrolytic capacitor alongside it and the Schottky diode.

It's more convenient to start with the smallest components – the resistors and capacitors, followed by the semiconductors and polarised components mentioned above. Don't worry about the loop or downlink wiring at the moment.

On the power supply board, three of the five components are polarised so make sure you get them in the right way. The potentiometer will only go in one way (otherwise the shaft points inwards!).

## Loop and downlink wiring

In the prototype, 4-wire telephone cable was used because this happened to be on hand – even though the loop antenna does not use the four individual wires (however, the downlink does).

Therefore you could just as easily use single-conductor wire for the loop if you wished. Note that telephone cable is quite a lot tougher than single wire and so offers some protection from, for example, birds sitting on it or even pecking at it!

If you use telephone cable for the loop antenna wiring, simply connect all four wires in parallel as you solder them to the PC board. The same applies for the output loop – the one which goes around your radio. The wires can be twisted together to make this easier. Note that all connecting wires solder to the pads on the underside of the PC board.

You might be wondering, as we did, why each single wire of the telephone cable was not connected in series with its mate and terminated as such on the PC board. Wouldn't this create a significantly greater inductance (ie, four times greater)?

We asked Oatley Electronics about this and they told us that originally they had exactly the same idea. Unfortunately, when they tried it out, they found that the capacitance of the closely-spaced wires within the cable started to create its own problems.

They found that by paralleling all four wires in the cable that this problem was eliminated. More importantly, they found that the overall performance of the antenna was better!

In the downlink, all four wires in the telephone cable *are* used independently and are connected to the points A,B,C and D on the PC boards.

With coloured wiring in the cable (black, red, blue and white) it's not easy to get it wrong!

This downlink wiring can be quite long – the prototype had 20m between the two PC board and there didn't appear to be any loss of signal compared to a 5m separation. If you need more distance, give it a go – you have nothing (except signal!) to lose.

## In use

If possible, make a complete turn around the radio receiver with the output loop (remember, the radio must have a ferrite rod for this antenna to work). How do you know if it has a ferrite rod antenna? If you can turn it on and it works without anything connected, it's a pretty fair bet that it has one! Virtually all small AM radios have a ferrite rod antenna inside.

Tune the radio to the weak station you want to listen to. Now adjust the potentiometer slowly – at one point, you should find a significant increase in the level of that station (or a decrease in other stations that are interfering with it).

Also recall what we said before about the antenna being able to turn so that it faces the wanted station – by facing, we mean broadside on, or if you take a line across the X frame the wanted station should be perpendicular to that line.

The antenna will work equally from both sides. However, if you turn the antenna through 90°, you should find that its performances decreases significantly and/or stations now broadside-on will be much better. SC

## WHERE FROM, HOW MUCH?

This project was designed by Oatley Electronics who retain the copyright. A kit for this project (K256), which includes both PC boards, on-board components and cases (as listed above) is available from Oatley Electronics, for $22.50 The kit does not include the 4-wire telephone cable nor any timber or mounting hardware.
Contact Oatley Electronics via their website: www.oatleyelectronics.com or call (02) 9584 3563.

# CIRCUIT NOTEBOOK

**Interesting circuit ideas which we have checked but not built and tested. Contributions from readers are welcome and will be paid for at standard rates.**

## Bi-directional variable speed drive includes regeneration

Designed for use in a self-balancing scooter, this variable speed pulse-width modulated (PWM) drive is bi-directional and includes regenerative braking to improve overall efficiency.

With PWM drives, the key to efficient regeneration is to make sure the pulse repetition period is at least an order of magnitude shorter than the effective time constant of the DC motor armature winding. For most motors, this means a pulse repetition frequency of 2kHz or more, although to be inaudible, above 20kHz is preferable.

Many "analog" drives use a sawtooth wave generator and a comparator circuit to generate the required PWM signal but often the pulse frequency is limited to only a few 100Hz. This design uses the internal PWM hardware module in a PICAXE-08M micro and the **pwmout** software command. This 'digital' approach resulted in a stable drive capable of up to 32kHz.

Neville Armstrong is this month's winner of a Peak Atlas Test Instrument

Software running in the PICAXE generates additional FWD and REV signals, which are then logically combined with the PWM signal to produce the appropriate gate signals (G1-G4) for four power Mosfets Q1-Q4 arranged in a conventional H-bridge.

It is very important with H-bridge configurations to ensure that both devices on one side of the bridge are NEVER switched on simultaneously, otherwise they will be destroyed. This is achieved by having "dead time" and is provided by flipflops comprising IC2c&d and IC5c&d. The RC circuits at pins 10 & 12 of the Schmitt trigger NAND gates ensure that, for example, the gate drive pulse for Q1 is removed 100ns before the drive pulse is applied to the gate of Q2, and vice versa.

By using both P-channel & N-channel power Mosfets, the need

| FWD | REV | PWM | Q1 | Q2 | Q3 | Q4 |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | Off | Off | Off | Off |
| 0 | 0 | 1 | Off | Off | Off | Off |
| 0 | 1 | 0 | Off | On | Off | On |
| 0 | 1 | 1 | Off | On | On | Off |
| 1 | 0 | 0 | Off | On | Off | On |
| 1 | 0 | 1 | On | Off | Off | On |
| 1* | 1* | 0* | Off | On | Off | On |
| 1* | 1* | 1* | On | Off | On | Off |

* Not permitted by the PICAXE software but not fatal for Q1-Q4 if it occurs

| | | BITS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| BYTE | 0 | VSD Address (0-7) | | | 0 | Speed Command Data (bits 7:4) | | | |
| | 2 | VSD Address (0-7) | | | 1 | Speed Command Data (bits 3:0) | | | |

## Contribute And Choose Your Prize

As you can see, we pay good money for each of the "Circuit Notebook" items published in SILICON CHIP. But now there are four more reasons to send in your circuit idea. Each month, the best contribution published will entitle the author to choose the prize: an LCR40 LCR meter, a DCA55 Semiconductor Component Analyser, an ESR60 Equivalent Series Resistance Analyser or an SCR100 Thyristor & Triac Analyser, with the compliments of Peak Electronic Design Ltd **www.peakelec.co.uk**

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for the usual supplementary power supply to drive the gates of the high-side Mosfets is avoided.

The TLP251 photocoupler devices not only provide the necessary low-impedance drive for the Mosfet gates very simply, they also provide optical isolation from the potentially noisy 24V, high-current circuitry.

In the software, an 8-bit speed command is sent to the PICAXE as two bytes of data via a serial input at pin P4. Each byte contains four bits of address data and four bits of the speed command data. This approach allows up to eight drives to be controlled from one RS232 serial port. The baud rate is 2400bps (8N1 frame).

The 8-bit speed command expected by the PICAXE software is a '2s-complement' binary number in the range +127 to -128. Full forward speed corresponds to +127 and full reverse speed corresponds to -127, with stationary corresponding to zero.

A speed command of -128 disables the drive by clearing both the FWD & REV signals, which results in all four Mosfets being switched off. This feature could be useful on those occasions when it is preferred that the motor coast to a stop rather than coming to a "controlled" stop with regenerative braking.

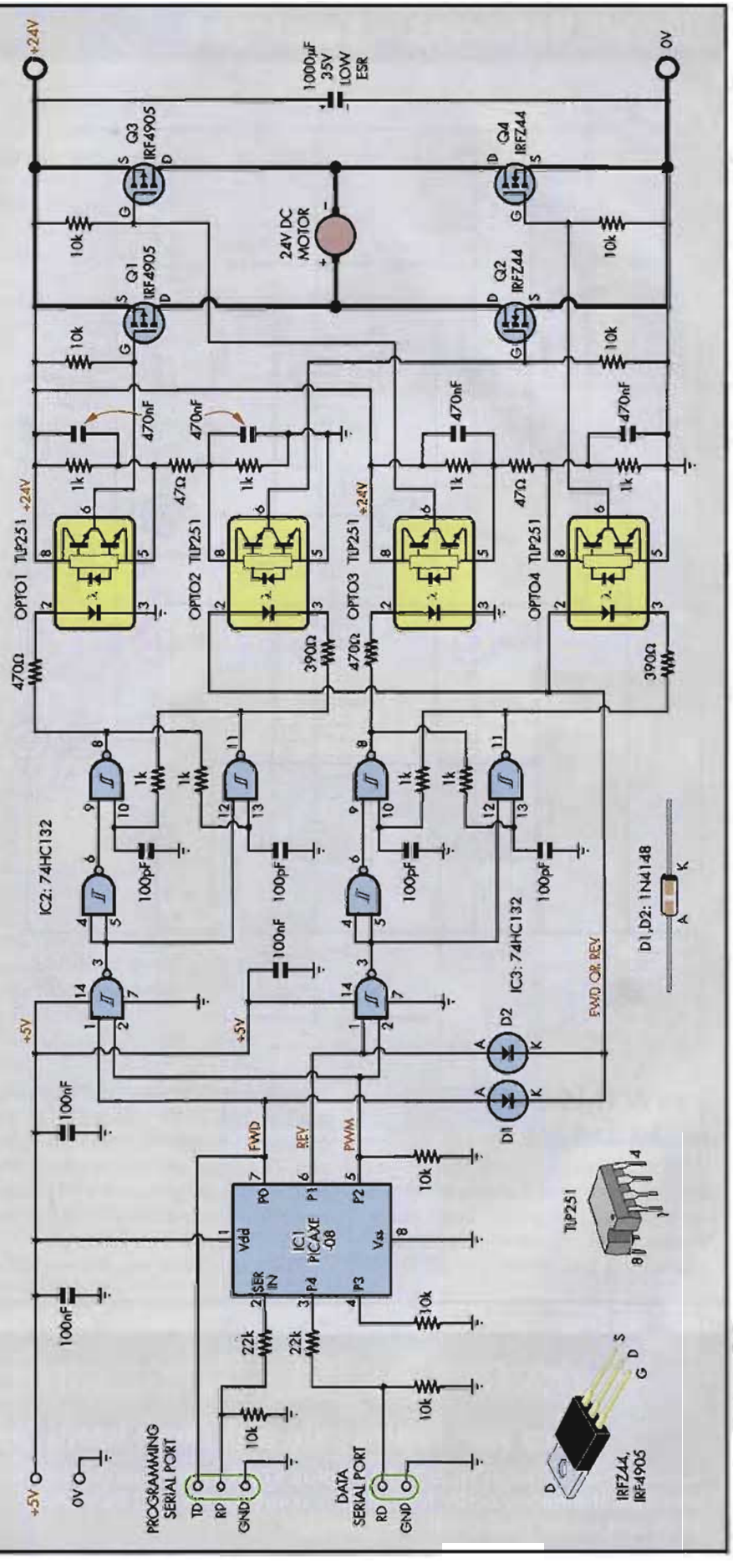
This circuit is very energy efficient. Apart from being regenerative, the switchmode operation ensures that power dissipation in the Mosfets is very low. When driving a 250W (12A) motor, and with minimal heatsinks, the Mosfets remain cool to the touch. Since each Mosfet is rated at above 40A, the drive should be capable of controlling motors up to 1kW with appropriately sized heatsinks and wiring.

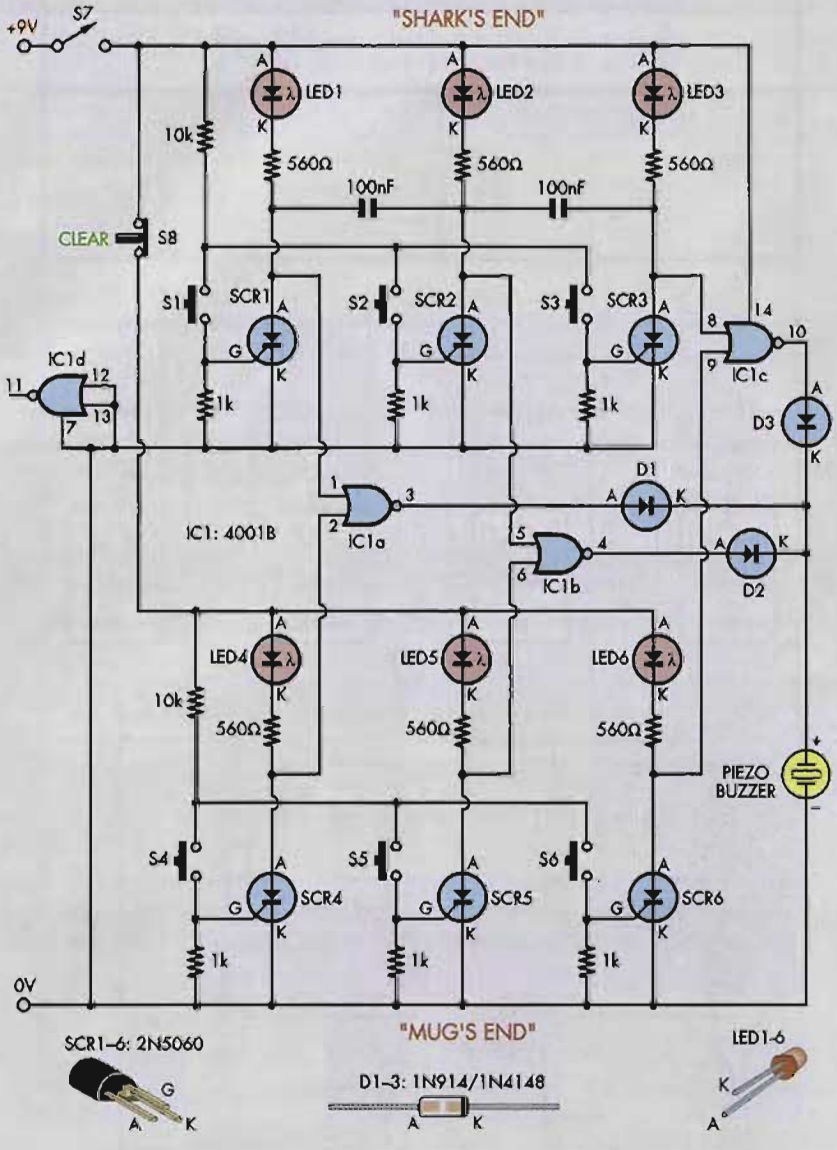
Note that a suitable fuse or other short-circuit protection will be needed for the 24V supply line.

The TLP251 devices are available from RS Components (Cat. 2610104), and the IRF4905 & IFRZ44 Mosfets are available from Oatley Electronics for about $6 a pair. The PICAXE-08M can be obtained from MicroZed for under $6, giving a total cost for all the semiconductors of around $50.

The software will be available on our website for download.

**Neville Armstrong,**
**Templestowe, Vic.**






## Pea & thimble or 3-card trick

This circuit is an electronic version of the old con game designed to separate the naive from their money. The operator (the Shark) moved the pea under one of three thimbles which were slid about on a table. The other player (Mug) put his money on the thimble hiding the pea. The game was made easy at first to allow the Mug to win a few times and allow his confidence to grow but he finally lost all his money.

The shark has a set of three LEDs and three pushbuttons. Pushing any button makes the associated LED light up. Pushing another button extinguishes the first LED and lights another. Hence, pushing the Shark's buttons "moves" the lit LED. The two dark LEDs represent the empty thimbles.

The Shark first shows how this works and you can arrange his buttons in the same order as the LEDs or to confuse matters, you can jumble the order. The Mug has to follow the pattern as demonstrated, easy or confusing. When the LEDs are later covered with three thimbles or opaque bottle tops, and the Shark is operating, the Mug can try to follow which LED is alight at any time.

The Mug also has three pushbuttons and three LEDs. When the Shark has finished shuffling, the Mug presses a button to light his LED opposite the one he thinks is lit. When the Shark's LEDs are uncovered, the Mug finds out whether he has won or lost. On the Mug's side is a normally-closed (NC) pushbutton switch to clear his LEDs.

Each player's LEDs are lit by a pulse applied to the gate of an SCR which stays on after the respective pushbutton is released. The capacitors between the SCR anodes on the Shark's side enable them to be turned off while the shuffling is occurring. This method of turning off SCRs is called "forced commutation".

IC1, the 4001 quad NOR gate, can be included to stop any sleight of hand tricks by the Shark when he (or she) is pressing the buttons. The NOR gates are connected with their two inputs connected to the respective LEDs on the Shark and Mug sides of the circuit. Thus, if the Mug presses the correct button, the respective NOR gate sounds the buzzer. This stops any dirty tricks by the Shark.

**A. J. Lowe, Bardon, Qld. ($50)**

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# Emergency Lights Controller

This emergency lights controller uses a PICAXE micro to provide a number of useful functions. A 12V battery which is permanently on "float" charge powers the circuit. A 3-terminal 5V regulator is used to power IC1 (the PICAXE micro), while the rest of the circuit runs from the battery supply.

The presence of mains supply is sensed by relay1; its contacts hold P4 of IC1 low. When the mains power fails, relay1's contacts open and P4 of IC1 is pulled high. Relay2 is then turned on via Q1, to connect the emergency lights which then stay on for five minutes, unless the over-ride switch (S1) is pressed. This 5-minute period is indicated by LED1 which flashes. This gives the user time to activate the over-ride switch but turns the emergency lighting off to stop the batteries from being expended if no one is home.

LED1 goes to steady in the over-ride/lights off mode if the over-ride button is not pressed within the 5-minute period. This allows easy location of the unit. If in the over-ride mode, the controller then toggles the lights on/off until the mains supply is restored. If mains power returns at any time, the controller returns to its standby mode.

When the mains power is present, the lights can be tested by pressing switch S1. This turns the lights on for five seconds to test relay operation. If pressed again during this 5-second period, a long test (65 seconds) is initiated. A third press stops the test. The long test is to allow checking of lights in other rooms.

When the lights are on, in mains fail mode, the battery voltage is checked via pin P2 and if the battery voltage is getting low, the buzzer chirps slowly, then faster as the battery voltage drops. Pressing the silence button, S2, turns the buzzer off. If the voltage drops to a lower level, the lights are turned off to prevent damage to the battery.

As well checking the battery voltage, via zener diode ZD1, P2 also drives the buzzer and responds to switch S2. The zener diode gives a range of 2-3V at P4 for a battery voltage of 11-14V. This translates to an ADC value of 100-150. Due to variations of values in the components, the values used in the code may need changing. This can be done by using programmer debug while reducing the power supply voltage.

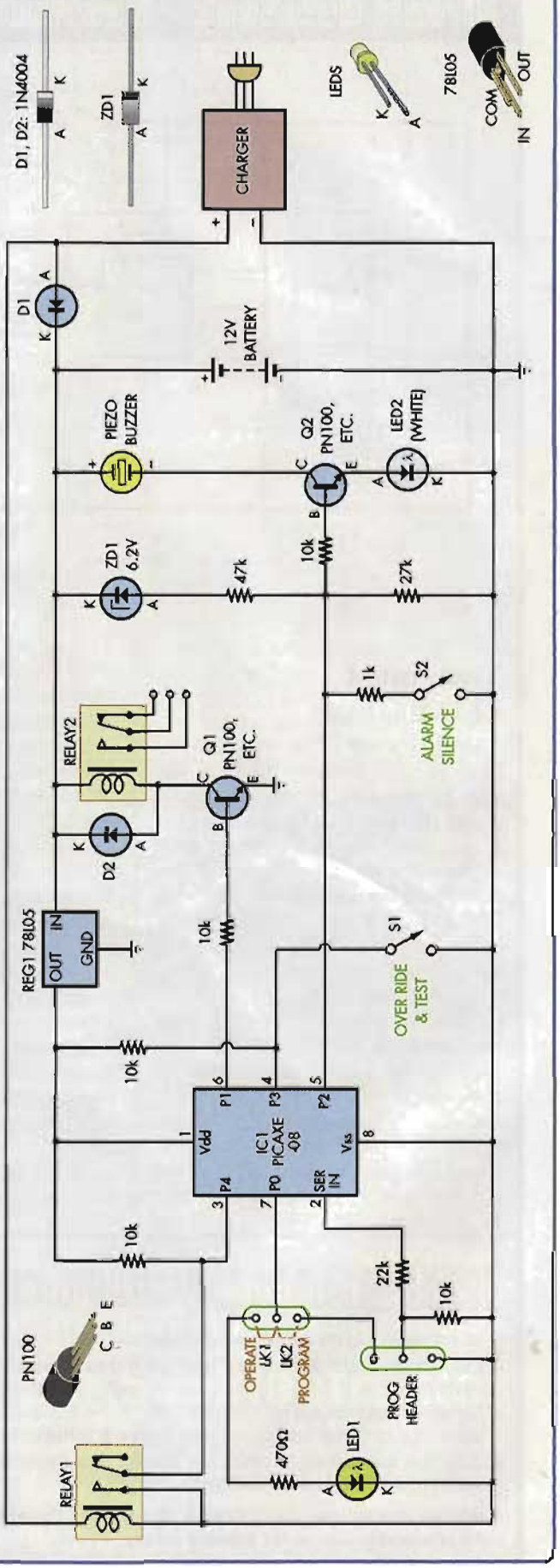
A white LED is used in the emitter of transistor Q1 to ensure that it is turned off unless it has least 3V at its base. If the battery float voltage is higher than about 13.8V, the transistor will be close to being on and at anything higher it will actually conduct. This can be prevented by increasing the zener voltage or putting another LED in series with the white LED. A red LED will give an extra 1.5V margin.

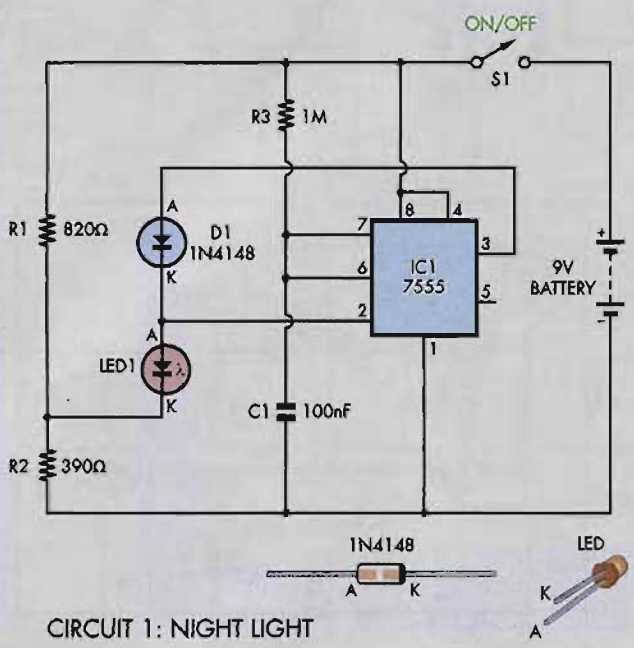
Interrupts are used to detect the operation of the over-ride/test button. This allows the button to be detected at all times, even if in the middle of a pause.

To set the value of the ADC to correspond to your selected alarm voltage, simply use the debug statement in the program to read the value of the ADC while reducing the input voltage to the alarm point. You will need to comment out all statements referring to P0 (pin 7), as these will affect the data being sent out on this pin. You will also need to change the link to the serial out.

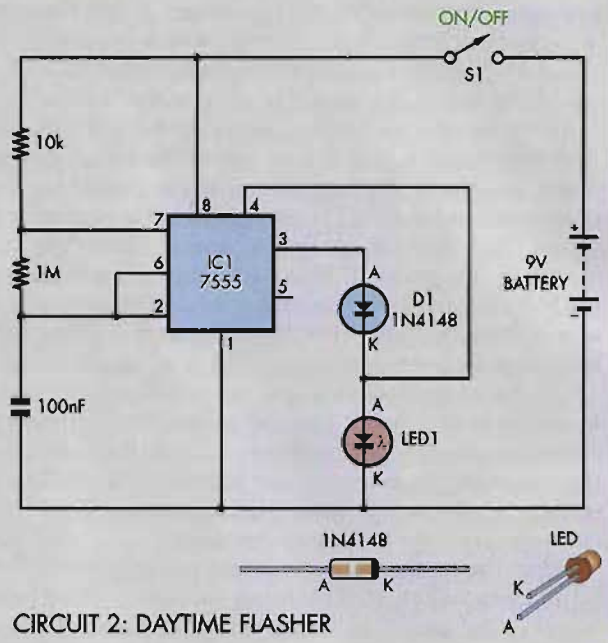
The software will be available on our website for download.

**Colin Carpenter, Mosman Park, WA. ($75)**






CIRCUIT 1: NIGHT LIGHT




CIRCUIT 2: DAYTIME FLASHER

## Two novel LED flashers

Ordinary red LEDs are normally used as light emitters but they can also be used as photo sensors. A single LED can even function as both a light emitter and a light detector in the same circuit. The basic idea is to flash the LED, using the "on" time to light it and the "off" time to sense the photovoltaic current from the ambient light that the LED "sees" when not turned on.

The two circuits presented here demonstrate how one LED can function as both a sensor and an indicator.

Circuit 1 functions as a "night-light" in which the LED stays off in normal light and turns on when the ambient light level drops. The 7555 CMOS timer is configured for monostable operation and triggers when the pin 2 voltage is less than 1/3 of the supply voltage.

Resistors R1 and R2 form a voltage divider which keeps the cathode of the LED below the trigger voltage. When the ambient light level is bright enough, the LED will develop several hundred millivolts across it which adds to the R1/R2 junction voltage and drives pin 2 above the 1/3 trigger level.

In this state, pin 3 of the 7555 will be near 0V and the 1N914 diode will be reverse biased, allowing the LED photovoltaic current to flow into the pin 2 trigger input.

When the ambient light level drops low enough, the LED voltage will fall and pin 2 will be below the trigger level. The 7555 will then generate a one-shot pulse, the 1N914 will be forward-biased and the LED will light up. At the end of the timing period set by R3 and C1 the monostable will reset and discharge C1, ready for another cycle. The LED will be turned off briefly during this time which allows it to sense the ambient light again.

Circuit 2 functions as a "day-light flasher", whereby the LED flashes in bright light and stays off in low ambient light. The LED operates as a light emitter when the 7555's pin 3 is high and as a sensor when the output is low. The 7555 is configured for astable operation and flashes the LED via the 1N914 diode as long as pin 4 (reset) is held above about 600mV. If the ambient light is too low, the LED will not generate enough voltage at pin 4 and the 7555 astable will be held in the reset state, the output will stay near zero and the LED won't turn on.

Note that the timer IC in both circuits must be a CMOS type because the circuit operates with very low input currents. Intersil ICM7555 devices were used in the prototypes; other devices may not work in Circuit 2 if the reset voltage required is too high.

**Geoff Nicholls,**
**Hamburg, Germany. ($65)**

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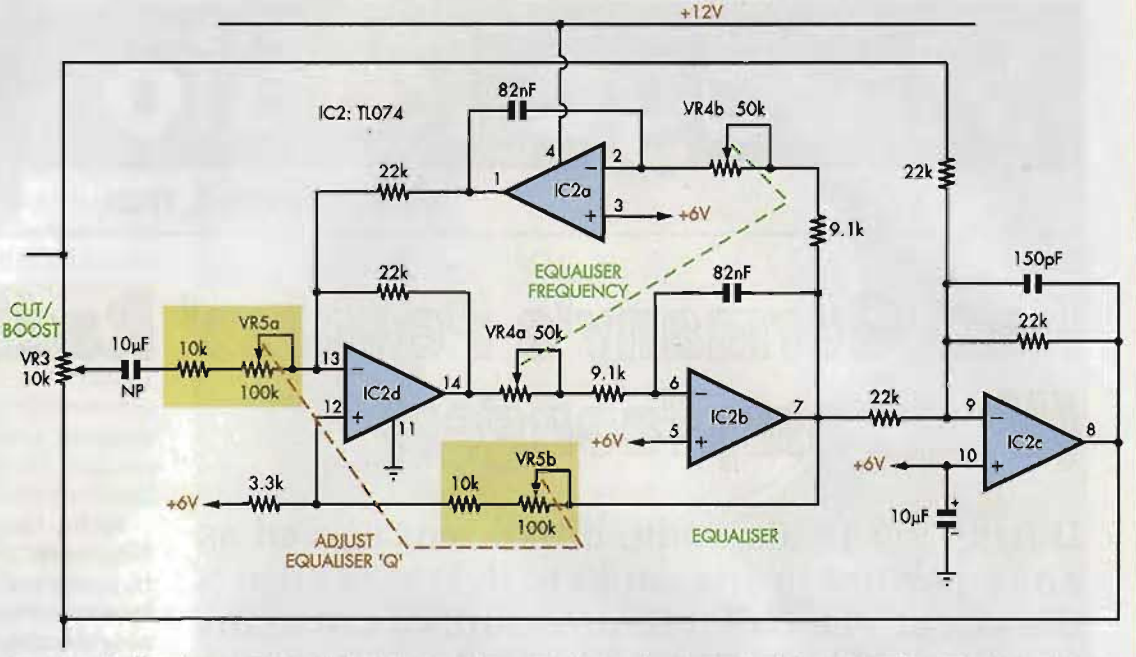
## Adjustable Q for subwoofer equaliser

The Subwoofer Controller in the August 2007 issue has just about all the features you could want but inevitably, there is always something else. In this case, it is an adjustable Q control for the parametric equaliser. This would allow the width peak or dip selected by the equaliser to be adjusted, which can be very noticeable, depending on the subwoofer itself and the listening room.




The accompanying circuit shows the additional components highlighted in yellow. VR5 is a 100kΩ linear dual-ganged pot. The separate resistive elements of VR5 and the associated 10kΩ resistors replace the 47kΩ resistors in the original circuit. This arrangement gives a Q adjustment range from about 1.3 to about 10.

Unfortunately, the extra dual-ganged pot cannot be fitted into the specified low profile plastic case but can be included if you build the Subwoofer Controller into the case for an accompanying subwoofer amplifier.

**Philip Chugg,**
**Rocherlea, Tas. ($30)**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# Vintage Radio

By RODNEY CHAMPNESS, VK3UG

# Nazi Germany's Peoples' Radio (Volksempfaenger)

**During the 1930s, radio broadcasts served as an important propaganda tool. It was also the era of The Great Depression, so not many people could afford high-priced radios. Nazi Germany's answer was a series of simple, low-cost "austerity" models.**

When Adolf Hitler's National Socialist Party (NSP) came to power in Germany in 1933, things quickly changed – much of it for the worse – in the depression-gripped country.

Radio receivers were a luxury item in Germany at that stage, as the manufacturers ran a price-fixing cartel. However, the NSP soon realised that radio could be a powerful propaganda tool and so a cheap radio that the average household could afford was needed.

However, they could also see that the average domestic radio of the day could pick up good-quality signals from adjoining countries. As a result, counter propaganda from these adjacent countries could cause German listeners to question what they were being told by the Nazis.

**The tuning dial in the DKE38 carries numbers rather than station markings. Note the Nazi emblem with the swastika and eagle immediately above the dial.**

So the Nazis they faced a dilemma. How could they encourage people to buy sets and listen to German radio broadcasts but not to broadcasts from neighbouring countries?

The solution was simple – keeping the price down so that the general population could afford the sets inevitably meant that they would be simple low-performance receivers. Their performance would be inferior to the more expensive sets, so the chances of them picking up good-quality broadcasts from other countries would be minimised.

To make absolutely sure that people only listened to German broadcasts, a label would be placed on the sets stating the following: "Be aware – listening to transmissions from across the border is a breach against the national security of our people. By declaration of the Fuhrer, it will be punished with severe jail sentences." Later in the war, the penalty for listening to "unapproved" radio stations was increased to death in some instances!

There were of course other more practical problems to be solved before the "Peoples' Radio" could become a reality. Unemployment was high in Germany in 1933 and flooding the market with cheap radios could cause many of the established radio manufacturing firms to collapse as sales of their high-priced receivers dwindled.

The NSP did not want more unemployment, so they asked a consortium of existing radio manufacturers to design a cheap, simple receiver. All manufacturers would then be directed to make these low-performance sets. And because the sets would be so basic, it was hoped that they would not

take sales away from the good-quality, higher-priced receivers.

## The Volksempfaenger & the Deutscher Kleinempfaenger

The first of these receivers was designed and built in 1933 as the model VE301. The "VE" stands for (V)olks(e)mpfaenger, while the "301" referred to the date Hitler became Chancellor of the Third Reich (ie, 30/1/1933). There are several variations on the meaning of the name, but the most common is "Peoples' Radio". Later the DKE ((D)eutscher (K)lein(e)mpfaenger) series was produced. The most common translation of this name is "German Small Receiver".

Subsequently, during the Hitler years from 1933-1945, at least 20 variations of the "People's Radio" were produced. Most models were designed to be used on mains voltages, either AC or DC, in the range 110-240V. However, some sets were designed to run exclusively on DC mains, while others ran exclusively on AC mains. Battery powered variants were also made for people located away from reticulated mains power.

It's worth noting that as time progressed, the original designs became even simpler. This was due to the manufacturers taking innovative steps to cut costs without impairing the performance of the receivers.

## Evolution

The first AC mains-powered model, the VE301W, used a transformer, which isolated the mains from the circuitry. An RGN354 rectifier was used in a slightly unusual circuit to provide 240V DC to the valve anodes, while an REN904 triode valve was used as a regenerative detector. The regeneration control consisted of a 180pF variable capacitor which was connected from the plate of the valve to the feedback winding on the single tuning coil.

In practice, the set would tune both long-wave (150-375kHz) and medium wave (500-1600kHz) frequencies over two bands. The changeover from band to band was accomplished via the tuning control. When a band change took place, the antenna tappings had to be changed as well.

The audio output from the regenerative detector was then coupled through a 1:4 (step-up) interstage transformer.

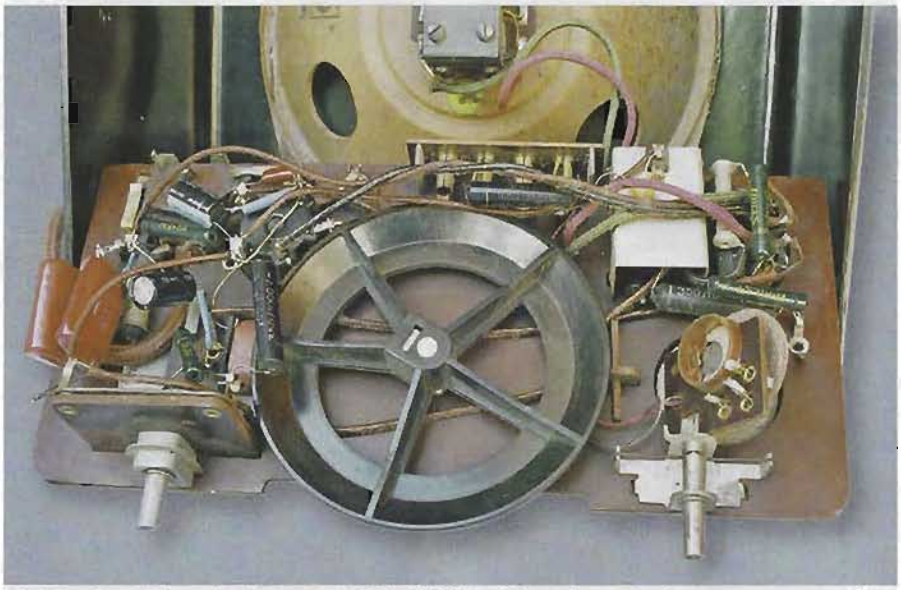
**The DKE38 was quite bland in appearance. The three controls (from left to right) are: aerial coupling, tuning (and band change) and regeneration.**

***This is the view inside the DKE38. The loudspeaker dominates the cabinet.***

This fed a directly-heated RES164 pentode audio output stage, which in turn fed a high-impedance reed speaker. The claimed sensitivity of the receiver was 1.5mV and the power consumption was stated as 21W.

The first DC mains receiver was the model VE301G. Because it ran

**The DKE38 is a transformerless AC/DC set and most of the parts run at lethal voltages. The 3-core mains lead (with the earth lead cut short) is a "ring-in". Note that tying a knot to anchor the mains cord (as shown here) is now illegal.**



**This is the under-chassis view of the DKE38. Note the swinging antenna coupling at right. The modern capacitor replacements at left look out of place.**

from DC, this had neither a power transformer nor a rectifier. The valve line-up differed from the VE301W as well, the VE301G using a REN1821 and a REN1823a.

In this unit, the valve heaters were connected in series across a 110V supply, while a tapped resistor was added in series with the heaters for higher DC supply voltages. Any rapid irregularities in the supply voltage were filtered using a conventional pi-type filter network consisting of two 4µF capacitors across the mains and an iron-cored choke between the capacitors on the positive line. As might be expected, the overall circuit configuration was virtually identical to that used in the VE301W.

## The DKE38

The DKE38 made its appearance some five years later, in 1938. The innovation that had taken place in those five years was quite obvious – it was a cheaper, simpler and capable of operating on either AC or DC mains in the range from 110-240V.

This set used two valves – a VY2 rectifier and a VCL11 triode/tetrode. There was still the same filtering arrangement on the mains as used in the VE301G but there was no power transformer. In addition, the interstage audio transformer was done away with and an RC network (which was cheaper) installed in its place.

The antenna connection system was also simpler than in the original sets and it was not usually necessary to alter the antenna tappings when changing bands. Another feature of the receiver was negative feedback between the plates of both stages.

All of this simplification did not come at the expense of sensitivity which was specified at 1mW. The set's power consumption was just 15W.

## Inside the DKE38

One of these DKE38 German People's radios was on display during the HRSA's recent 25th anniversary celebrations and I was able to take a good look at it. This receiver is quite obviously an austerity model, as it is very much a "plain Jane".

The controls from the left to right are: aerial coupling, tuning (and band change) and regeneration. There is no volume control as such, probably because the receiver isn't particularly sensitive, plus the regeneration and aerial coupling can achieve a measure of volume control, albeit with some degradation of the set's performance.

An interesting omission is the lack of protection for the speaker, unlike Australian-built sets of the same era which had bars as part of the Bakelite cabinet moulding. In addition, the tuning dial only has numbers on it, rather than the station markings.

There was one other interesting feature here – just above the tuning control was an emblem displaying an eagle and a swastika. Did the German people really need reminding of the regime they lived under!

The rear of the set is completely covered with a perforated pressed-cardboard panel. This panel also carries a few instructions and has information on attaching antennas and an earth to the set.

**Of course, it is necessary that this cover remain in place, as the DKE38 is a "hot chassis" unit. In other words, mains voltages are present just about everywhere inside the set.**

In fact, a set like this should only be operated with all covers on or via an isolation transformer. An isolation transformer, for those unfamiliar with them, is used to isolate a receiver's

circuitry from the mains, to make it safer to work on. However, that is not an invitation to be careless.

The rear panel also carries what appears to be the remnants of the mains on-off switch (near where the power lead enters the receiver). This is no longer in use in this particular set.

The set's cabinet is reasonably large, considering how little it houses. It measures 24cm high x 24cm wide x 12cm deep and the loudspeaker is the dominant part. The complete unit weighs just 2kg, which is very light.

Removing the back cover shows just how simple this set is. On top of the chassis are two valves, a couple of filter capacitors, a tapped wirewound resistor, a coil, a small filter choke, the tuning capacitor and a fuse. The loudspeaker is attached to the inside front of the cabinet.

Removing the chassis from the case involves removing two knobs at the front and two screws towards the rear of the set. Turning it over shows that the underside of the chassis carries only a handful of components. Even here, there is Nazi propaganda – most of the original components had the eagle and the swastika marked on them.

Unlike other sets of the era, the chassis is made from a phenolic type material. This not only acts as a chassis but also as an insulator for the various components. Apparently, the shielding benefits of a metal chassis were considered unnecessary in a low-cost set such as this, although some "hand capacitance" effects would probably have been evident when tuning.

In particular, this could have caused detuning effects or loss of sensitivity during tuning. It may even have caused the set to go into oscillation in some circumstances.

The loudspeaker is around 200mm in diameter, which is quite large for such a simple set. However, a large speaker would be more sensitive and would give greater volume than a smaller unit. An additional advantage was that the set was so big that it could not easily be hidden, so the eagle and swastika would always be on display.

One unique feature of the speaker is that its frame is made of compressed cardboard. No doubt it was treated and sealed so that it did not absorb moisture, otherwise it would have quickly distorted and caused the speaker to malfunction. But why make the speaker frame out of cardboard? The answer is that Germany needed all its steel for use by the military, so these sets used the minimum amount of metal in their construction.

**Because it is a "hot-chassis" set, the rear of the DKE38 is completely covered with a perforated pressed-cardboard panel.**

**A bird's-eye view of the top of the chassis. To keep costs down, the chassis was made of a phenolic-type material rather than metal.**

## Circuit details

Fig.1 shows the circuit of the DKE38. The first stage functions as a regenerative detector and it tunes both the long-wave and the medium-wave broadcasting bands. Shortwave was not included, since the aim was to prevent users tuning to distant stations instead of listening to broadcasts from the Nazi propaganda machine.

As shown in Fig.1, the antenna input

## Photo Gallery: Aimaster TRF Console (1931)

**MANUFACTURED BY TARGAN ELECTRIC PTY LTD (MELBOURNE) in 1931, this 3-valve TRF console receiver was fitted with an 8-inch (20cm) electrodynamic speaker and was housed in a long-legged wooden cabinet, a style that was popular during that era.**

**The valve line-up was as follows: E442 detector; B443 audio output; and 280 rectifier. Photo: Historical Radio Society of Australia, Inc.**

consists of three input points to allow for different sized antennas. However, sets with low sensitivity require both an antenna and an earth if they are to work effectively, so an earth terminal was also provided.

The input coil is physically isolated from the rest of the circuit to make sure that it does not operate at mains potential. In practice, a swinging-coil arrangement is used to alter the coupling of the input antenna coil to the tuned winding to optimise reception.

The tuned circuit is a conventional regenerative arrangement for a triode detector. The regeneration (reaction) is controlled by 180pF variable capacitor, while a 320pF variable capacitor takes care of the tuning. Note that this tuning capacitor is capable of rotating a full 360° – the first 180° tunes one band, while continued rotation through the second 180° either switches the second secondary winding in or out to tune the second band. This is achieved using a cam, which in turn actuates the switching (a very nifty idea).

The detector stage is RC coupled to the audio output stage. This is also quite conventional, although it is interesting to see that negative feedback is provided between the plates of the two valve sections. A 600Ω adjustable resistor provides the bias for the audio output stage valve and was probably adjusted in the factory when the radio was set to operate on 110, 150 or 240V. The plate voltage will vary depending on what mains voltage is available, hence the bias would also need adjustment.

The speaker is a high-impedance (balanced armature) type which saves using a speaker transformer.

### Power supply

The power supply is similar to that used in many AC/DC type sets. The circuit shows that the mains is switched in both leads but in reality, this probably consisted of a linking system that was broken if the back of the set was removed. However, I can't be sure of this, as this mechanism is incomplete in this particular receiver.

As shown, one side goes through a fuse and is followed by an adjustable 600Ω resistor. This then provides the common "earthy" line for the circuit. On the other line, the voltage dropping resistor to the heaters of the two valves is selected using a "wander" lead. This is then followed by the 30V 50mA heater of the VY2 rectifier and the 90V 50mA heater for the VCL11 triode/tetrode valve before going back to the other side of the mains.

One side of the mains is also applied directly to the plate of the VY2 rectifier. The rectified output is taken from the cathode and is fed to the filter network consisting of two 4µF capacitors and an iron-cored choke in a pi filter network. A 10nF capacitor is also wired across the VY2 rectifier to get rid of any high-frequency spikes.

In view of its low-cost design philosophy, it initially puzzled me that an iron-cored choke was used in the filter network instead of the simpler and cheaper resistor option used in later domestic radios. In the end, I concluded that they couldn't use a resistor because the voltage drop across a resistor that was effective enough to act as a filter element would have been too great. In fact, the audio output with a 110V supply is down to just 0.25W, increasing to 1.2W on 240V.

High-value electrolytic capacitors were not available in those days either, so the iron-cored choke was a necessity.

### Miscellaneous

The DKE38 receiver was certainly made of lightweight materials, the speaker drive mechanism and the filter choke being the only components with windings and a metal core.

It's an interesting receiver, if only for

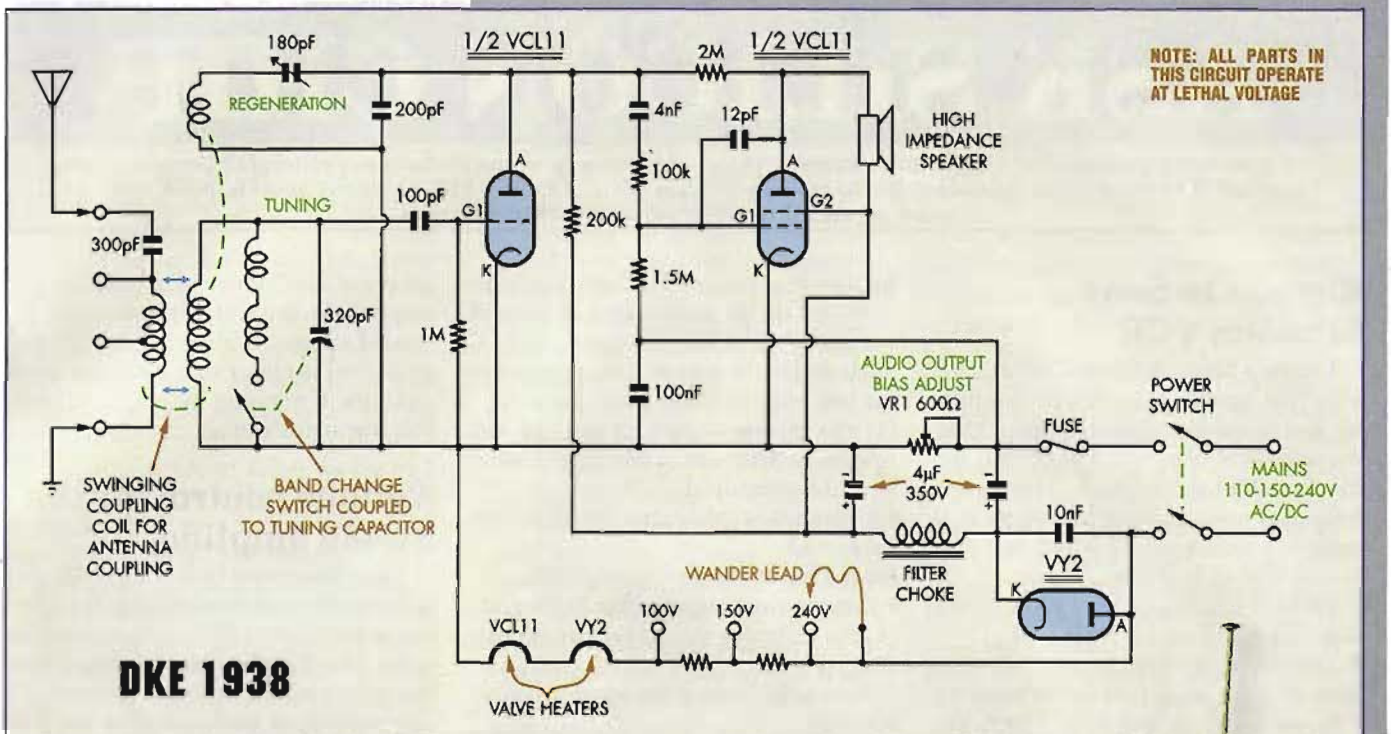



**Fig.1: the circuit of the DKE38. The first stage functions as a regenerative detector, while the second stage is the audio amplifier. Note that all parts in this circuit, except for the antenna input circuit, operate at lethal voltages.**

its design philosophy. It's also interesting to note that the Telefunken VY2 and the VCL11 valves were designed specifically for the German Peoples' Radios.

Other countries also produced "austerity type" radios, one example being the Austrian R2 set of 1939 – see photo. It wasn't as austere as the German set though, as the R2 was a 6-valve superhet which covered the long-wave, medium-wave and short-wave bands. The German army later used this model extensively.

Britain also had its own equivalent. Called the "Utility Receiver", it was built by various manufacturers to a government-approved standard. Basically, it was an austerity model that used standard components and a simple design to economise on scarce raw materials and to make repair easier.

However, despite its simple design, it was quite capable of picking up the Nazi broadcasts, a practice that was discouraged but not forbidden.

**The Austrian-made R2 is a 6-valve multi-band superhet that was used extensively by the German army during WW2.**

## Summary

The set featured in this article was obtained by its current owner, Ian Johnston, after a previous owner had carried out some "restoration" work. Unfortunately, that owner had not taken the time to disguise several new components inside the old component cases and the new parts look out of place in the chassis.

The mains lead was also replaced with a 3-core item, which is out of place on such a set since the earth lead is just cut off anyway! In fact, using a twin lead and an isolation transformer is the safest way of running an AC/DC receiver like this.

Even so, a high-voltage insulation test between the antenna/earth connections and the mains should be carried out before even trying to use a set like this, in case of an insulation breakdown. These old AC/DC sets can be death traps for the unwary! SC

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## Repairs to Sony Betacam VCR

I have a Sony Beta SL-C80AS PAL VCR that has faulty audio (wow & flutter and some distortion). I am looking for someone who could service it for me. I am 90km from Gosford, so do not have easy access to specialised service outlets. I have a pile of Beta tapes that I wish to dub to DVDs.

I would appreciate any help you can offer. (P. K., Gosford, NSW).

• We have spoken to our Serviceman and he says that unfortunately you have left it too late. There are few parts and even fewer technicians interested in fixing complex 20+ year old Betas.

His advice is to change the pinch roller, roughen the upper and lower head drums to prevent stiction (without damaging the heads) and make sure the reel brakes are not stuck on. In addition, clean the ACE head (make sure it is not worn out) and change the electros in the power supply.

## Appliance energy meter for the USA

I live in the USA and your construction article for the Appliance Energy Meter (SILICON CHIP, July/August 2004) doesn't make it clear whether it is suitable for 115VAC. Please clarify. (B. M., Minneapolis, USA).

• We designed the Energy Meter for the Australian and New Zealand 240VAC 50Hz mains and it should work as well for the European 220VAC 50Hz mains. However, it is not suitable for use with 115VAC 60Hz because:

(1) the power supply would be too low and a different mains transformer would be required;

(2) the unit is calibrated for 240V and up to 15A;

(3) the input voltage measurement divider requires changes for 115V and;

(4) the software would require rewriting.

Sorry, it cannot be used in your country.

## Searching for transistor equivalents

Some time ago, I bought a publication about semiconductors (transistors, thyristors, diodes, ICs and so on) in an attempt to assist in locating compatible semiconductors (mostly transistors). While searching for a PN2222 NPN type transistor, I opened this book only to find I need to know the type (for example 1N1907 or 2SC1556 or 74177) to alphabetically locate this particular semiconductor.

Where is this information as to semiconductor types so that I can try to figure out this "Up-To-Date Worlds Semiconductors" book please? (C. H., via email).

• The best way to solve such problems is to do a Google search. This will give you the device specs and then you can decide on a suitable substitute. We would suggest a BC547 although you still need to check that it has the same pinouts. If not, you may have to bend the transistor's leads to match.

## Volume control for the SC480 amplifier

I am interested in building the SC480 amplifier as described in the January & February 2003 issues of SILICON CHIP. The question is: where and how do you provide volume control for the output? Is there another module required for this? (M. P., via email).

• Yours is a very common question, pertaining to many amplifier modules that we have described over the years. The approach is very simple and has been most recently illustrated in the direct volume control connection for the Stereo 20W Class-A Amplifier - see page 75 of the September 2007 issue. You just hook up the volume control pot (10kΩ log) to the input signal. No extra module is required.

## Inverter transformer for the valve preamp

I have been unable to get the 12AX7 valve audio preamplifier project (SILICON CHIP, November 2003) from Jaycar electronics as they no longer stock this kit. I am confident of finding most of the parts on the list except the

## Starship Enterprise Door Sounder Mods For Switch Operation

I have recently finished building the Starship Enterprise door sounder (SILICON CHIP, June 2006) and it works fine. However, I noticed space on the PC board for two capacitors, two 220kΩ resistors, a JP1 jumper and a terminal block TB2 marked S3-S4. Does this mean the unit can be operated from an extra set of switches?

Also, with out trying to be disrespectful, if it was difficult simulating the sound, why not simply record the original sound from the TV show onto the chip? (G. G., Wollongong, NSW).

• As you have guessed, the Starship Enterprise door sounder can be arranged to operate from an extra set of switches, by adding the extra components. When this is done though, there must be a recorded sound for each of the four switches, so each sound can use only one quarter of the chip's memory. In other words, the project then can deliver one of four short sounds, instead of one of two longer sounds.

The sounds that were finally programmed into the recorder chip for this project were in fact taken from a recording of the TV show, as we did find it too hard to simulate.

## Input Offset Adjustment For Class-A Amplifier

About a year ago, I built your old version of the class-A amplifier (SILICON CHIP, July & August 1998). I have since been using it every day connected to Quad ESL 57 electrostatics without any problems and with plenty of volume.

So I think that your new 20W version should be quite sufficient as far as power goes. Also, if you use amplifiers with higher power than 25W, a protection circuit must be fitted as Quad ESLs, as far as I am aware, are only rated at 25W RMS.

If volume is low with ESLs, then it is most probably due to the EHT block, which requires a service. In your reply to a letter in the July 2007 issue (page 98) you spoke of a trimpot in the emitter of the differential input stage and diodes connected across both transistors so the new version 20W class A could be used with ESLs. Is all this really necessary, especially as mine, admittedly the old version, works perfectly and sounds great?

Incidentally, it is even better than a 25W per channel single-ended valve amplifier using 300B output valves that I also have. (C. A., via email).

● Strictly speaking, any solid-state amplifier driving transformer loads (such as your ESLs) should have the circuit features referred to.

If you measure the offset voltage of your amplifier and also the DC resistance of the transformer's primary winding (ie, the DC resistance across your ESL's speaker terminals), you can calculate the DC current which flows in the transformer primary.

For example, if your amplifier's DC output voltage is +50mV and the transformer's primary resistance is 100mΩ, then the standing current will be 500mA. This will lead to overheating and distortion in the amplifier and will also cause additional distortion in the transformer due to the gross shift in its B-H curve. Ideally, any DC current through the transformer should be at an absolute minimum.

In fact, even the suggested DC output offset value of ±5mV could result in a DC current of 50mA. Ideally, any DC current in the primary of the ESL's transformer should be no more than a few milliamps.

To measure your amplifiers' DC output offset voltages, just connect your digital multimeter across the speaker terminals (with the speaker disconnected), for each channel. Use the 200mV DC range and the reading should normally be within less than ±50mV DC. For example, our new prototype class-A modules, as mounted in the chassis pictured last month, have DC output offsets of +7mV and +44mV DC.

As built, your class-A amplifier might have an output offset voltage of only a few millivolts, in which case there is no problem. But it could easily be a lot more. And if you like playing classical music at even reasonable levels, you do run the risk of running the amplifier into clipping and the subsequent risk of damage due to transformer-induced spikes. Occasional modest clipping may not cause a problem but heavy clipping carries a large risk.

To provide an offset adjustment, connect a 100Ω trimpot between the two 100Ω emitter resistors for Q1 & Q2. The method is shown in the circuit of the Studio 350 amplifier featured in the January 2004 issue.

We must emphasise, however, that we have not tested the class-A amplifier module with this modification.

converter transformer (T1). Altronics looked for it but they had a different type of core and I'm not sure if the same thing can be achieved using it instead.

Also in the article it is mentioned that the secondary winding is done in two layers but are these two layers wound in opposite directions from each other? I would appreciate it if you could tell me where I can obtain the converter transformer (T1) or if there is an alternative solution? (A. A., via email).

● Both the preamplifier and inverter PC boards (board numbers 01111031 & 01111032) for this project can now be obtained from RCS Radio Pty Ltd. Phone (02) 9738 or **www.rcsradio.com.au.**

The original article gave fairly complete details for winding the converter transformer and you could probably wind it on a similar core if this is all that you can obtain, assuming it's of roughly similar size. The two layers of the secondary winding are wound in the same direction around the centre leg of the core (ie, both clockwise), but with the turns progressing from the start end to the halfway point in the first layer, and then back to the start for the second layer.

The main point to watch is that after winding the first layer, you cover it with a layer of PVC tape before winding the second layer over it.

## Mixer mods required for acoustic guitar pickup

Referring to the Versatile 4-Input Mixer described in the June 2007 issue, what component values would you suggest for an under-saddle piezo pick-up (passive) in an acoustic guitar? (J. G., via email).

● To accommodate any ceramic pick-up for use in acoustic guitars, violins etc, we would make the following changes to one input of the mixer. Assuming this is input 1, omit Rm1a and link across Rm1b; omit Rin1 and the 2.2µF input coupling capacitor; make Rza1 & Rza2 both 10MΩ; make Rf 4.7kΩ and Cf 1nF. If you find that you need more gain, increase the value of Rf.

## Preamp gain varies between channels

I recently built the headphone amplifier and preamplifier featured in the October 2005 issue. I have used two different brands of 2200µF capacitor in the power supply and the voltage is 0.1V lower on the positive output than the negative. Is this a problem?

Would this contribute to the sound being slightly louder in one channel than the other? The intensity of the

## Questions On The Programmable Ignition

I have a few questions regarding the Programmable Ignition MkII kit (March, April & May 2007). First, where can the Sensym map sensor be purchased?

Second, are you able to explain the setting "response to low RPM" to me in more detail? How does this function actually work and how does the RPM setting you define play its part? The description in the manual on exactly what this setting does is very vague.

Thirdly, does the max RPM act in any way as a rev limiter? Will it drop sparks if you exceed this RPM or what happens? (J. P., via email).

• The full details on where to buy the Sensym sensors was published in the April 2007 issue of SILICON CHIP on page 76. The Sensor can be obtained from Farnell (**www.farnellinone.com.au**) or RS Components (**www.rsaustralia.com**). The actual sensor depends on whether you have turbo or supercharger boost. The details are on the abovementioned page.

Response to low RPM means the RPM below which the calculation for timing is made between each trigger edge before the spark is triggered. This is to speed up the response at low RPM where engine revs can change very quickly. In practice, the setting only needs to be at or below the idle RPM.

No engine RPM limiting is provided. The max RPM refers to the mapping limit of the advance curve.

There is no easy way to provide limiting using spark control without richening the mixture and making the engine prone to backfire. This could be more detrimental to the engine than over-revving.

sound seems to slightly roll from one channel to the other but apart from that I am happy with the results. (A. R., via email).

• Slight differences in the capacitors and the supply rails should have no effect on the preamplifier's performance. However, it should not be audibly different in the left and right channels. This suggests that some resistor values may not be the same in both channels or that the ganged volume control does not track well in both channels.

## 100Hz ripple due to faulty capacitor

Could you please explain what the likely causes of ripple current in amplifiers would be? I'm having problems with an old "Electronics Australia" 300W subwoofer amplifier that I've built.

This amplifier module is part of a pair that to date has worked flawlessly but after a period of about three months of inactivity, one has now developed what I suspect to be ripple current hum (I'm pretty sure it is not an earth loop, as nothing has been changed in the wiring).

I have about 50,000µF filtering across each rail. If one of the filter capacitors has died and caused an imbalance, would this be the source or something else? I'm not sure if this is the case though, as there's no switch-off thump when the power is removed. (P. S., via email).

• If your amplifier has suddenly developed ripple current symptoms (ie, audible 100Hz buzz), the most likely causes are a poor solder joint or a capacitor (or capacitors) which has developed high internal resistance.

## Lead length limitation on keypad alarm

I am building the Keypad Alarm as published in the April 2003 issue of SILICON CHIP. I intend situating the keypad & circuit board some distance apart and note that you say that the maximum lead length should not exceed 200mm (page 34, Fig.4). 400mm would suit me better. How important is this limitation in lead length? (N. W., via email).

• The limitation on the length of wire connecting the keypad to the main PC board is due to the possibility of false keypad detection with longer leads. When using longer leads, we would recommend adding pull-up resistors at the four inputs to the keypad (RB4, RB5, RB6 and RB7 at pins 10, 11, 12 and 13 of IC1). The resistors can be 1kΩ but for lengths over 1m, a lower value may be necessary.

Values down to 330Ω may be required to prevent false keypad entry detection. The pull-up resistors connect to the +5V supply (available at REG1's output and at pin 14 of IC1).

## LEDs for Video Reading Aid

I am gathering together the parts required to build the Video Reading Aid described in December 2005. The kit looks to be quite useful, as commercial


**WARNING!**

SILICON CHIP magazine regularly describes projects which employ a mains power supply or produce high voltage. All such projects should be considered dangerous or even lethal if not used safely.

Readers are warned that high voltage wiring should be carried out according to the instructions in the articles. When working on these projects use extreme care to ensure that you do not accidentally come into contact with mains AC voltages or high voltage DC. If you are not confident about working with projects employing mains voltages or other high voltages, you are advised not to attempt work on them. Silicon Chip Publications Pty Ltd disclaims any liability for damages should anyone be killed or injured while working on a project or circuit described in any issue of SILICON CHIP magazine. Devices or circuits described in SILICON CHIP may be covered by patents. SILICON CHIP disclaims any liability for the infringement of such patents by the manufacturing or selling of any such equipment. SILICON CHIP also disclaims any liability for projects which are used in such a way as to infringe relevant government regulations and by-laws.

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**Conversion From RPM To Frequency For Engines With One To 12 Cylinders**

| Cylinders | 1000 RPM | 4000 RPM | 4500 RPM | 5000 RPM | 5500 RPM | 6000 RPM |
|---|---|---|---|---|---|---|
| 1 (4-stroke) | 8.33Hz | 33.33Hz | 37.5Hz | 41.67Hz | 45.83Hz | 50Hz |
| 2 (4-stroke), 1 (2-stroke) | 16.67Hz | 66.67Hz | 75Hz | 83.33Hz | 91.67Hz | 100Hz |
| 3 (4-stroke) | 25Hz | 100Hz | 112.5Hz | 125Hz | 137.5Hz | 150Hz |
| 4 (4-stroke), 2 (2-stroke) | 33.33Hz | 133.33Hz | 150Hz | 166.67Hz | 183.33Hz | 200Hz |
| 5 (4-stroke) | 62.5Hz | 250Hz | 281.25Hz | 312.5Hz | 343.75Hz | 375Hz |
| 6 (4-stroke), 3 (2-stroke) | 50Hz | 200Hz | 225Hz | 250Hz | 275Hz | 300Hz |
| 7 (4-stroke) | 218.75Hz | 875Hz | 984.38Hz | 1.09kHz | 1.20kHz | 1.31kHz |
| 8 (4-stroke), 4 (2-stroke) | 66.67Hz | 266.67Hz | 300Hz | 333.33Hz | 355.66Hz | 400Hz |
| 9 (4-stroke) | 75Hz | 300Hz | 337.5Hz | 375Hz | 412.5Hz | 450Hz |
| 10 (4-stroke), 5 (2-stroke) | 83.33Hz | 333.33Hz | 375Hz | 416.67Hz | 458.33Hz | 500Hz |
| 11 (4-stroke) | 91.67Hz | 366.68Hz | 375Hz | 416.67Hz | 458.33Hz | 500Hz |
| 12 (4-stroke), 6 (2-stroke) | 100Hz | 400Hz | 450Hz | 500Hz | 550Hz | 600Hz |

**Rev Limit Controller, April 1999:** the section describing the setting of the rev limits on pages 87-88, by revving the engine in a low gear while travelling along a quiet street and while a passenger makes the adjustments, is no longer recommended. Instead, we advocate using a signal generator to set each limit point.

The signal generator needs to have at least a 5V peak-to-peak square wave output. A suitable generator is the Jaycar QT-2302.

The signal from the generator is applied between the low voltage input and the 0V terminals of the Rev Limit Controller. Readers who have built the reluctor input version will need to add ZD2 and the two 1kΩ resistors that are associated with the low-voltage input circuit. The two 1kΩ resistors are those just above ZD2 on the overlay diagram (Fig.6).

The above table shows the frequencies that correspond to engine RPM for various engine types. Select your engine and the RPM you require for each setting. Now set the frequency generator to the frequency shown and adjust the trimpot associated with the lamp to just light at that frequency. For the Jaycar QT-2302, set the frequency range to x1 for up to 1.5kHz, with the amplitude set fully clockwise and with the square wave setting and 0dB attenuation.

Note that the Jaycar QT-2302 has frequency adjustments in steps rather than as a continuous range of adjustment. For this generator, select the frequency that is closest to the one you want.

If the RPM you require is not shown in the table, refer to the 1000 RPM values in the table. The frequency value can then be scaled up for your desired RPM. For example, if you require the Rev Limit Controller to switch at 6200 RPM for a 4-cylinder 4-stroke, multiply the 33.33Hz value for 1000 RPM by 6.2. The result is 206.65Hz.

readers cost in excess of $3000. It is a pity that none of the parts retailers has put the kit together.

The kit specifies high brightness LEDs. What mcd and mW output were used in the kit that you constructed? I have located some that range up to 18,000mcd and 120mW. I suspect that these would consume too much power for the intended 12V power supply? (D. M., via email).

- It sounds as if you are proposing to use the same 5mm white LEDs that were used in the prototype Reading Aid. They are available from Jaycar as ZD-0195 and have a maximum power rating of 120mW and a typical output of 18,000mcd at 30mA. These LEDs provide more than enough lighting in the Reading Aid, where they are run at a current level of around 20mA. SC